TDS-90-01 (MTO)
TP 10473E (TDC)

An Overview of Available and Developing Highway Vehicle Electronic Technologies

Ontario
Ministry
of
Transportation

Transportation
Technology and
Energy Branch

Transport Canada
Transportation Development Centre

91-00828/

DISCLAIMER

The contents of this report reflect the views of the contractor and are not necessarily the official views or opinions of the sponsoring agencies:

- Ministry of Transportation, Ontario
- Transportation Development Centre of Transport Canada

A summary of this report in French is included on page xix.

Un sommaire en français de ce rapport est inclus à la page xix.

Technical Report Documentation Page

An Overview of Available and Developing Highway Vehicle Electronic Technologies

Prepared by: **Jouko A. Parviainen, Parviainen & Associates**

Prepared for: **E. Ryerson Case**
(416) 235-4676

Report No.: TDS-90-01 (MTO)
TP10473E (TDC)

Date: October 1990

Published by: Transportation Technology and Energy Branch
Ministry of Transportation, Ontario

Abstract:

The forerunner to this project, the Mobile Information Systems Impact Study (TDS-88-07, TP 9360E), presented a state-of-the-art review on devices which can display a vehicle's position relative to a map data base and which support navigation or route guidance functions. This Highway Vehicle Electronics project was initiated to review the complementary technologies of automatic fleet monitoring, vehicular monitoring/control and travel support systems, and to present a brief update on navigation systems. The two reports together establish a knowledge platform for reviewing critical issues in the development of on-board electronic technology toward increasing the safety and productivity of the road transport system.

This report provides a technology primer on highway vehicle electronic systems and their applications. It highlights the need for an integrated intelligent system, and recommends that all systems intended to support navigation, manoeuvring and control tasks receive a full human factors evaluation covering physical, perceptual, cognitive and motivational abilities and limitations.

The report recommends that coordinated action be taken in Canada involving government, industry and academia to take advantage of the many opportunities presented by recent developments in intelligent vehicle/highway systems technology. These include commercial development of new products, basic and applied research and the potential to substantially improve the cost-effectiveness of the roadway system in terms of increased productivity and reduced fuel consumption and air pollution.

Key words: Highway, vehicles, fleets, monitoring, control, human factors, traveller support, markets, identification, classification, location, weigh-in-motion

Distribution: By request

Copyright Status: Crown copyright

Transport Canada Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No.
TP 10473E

2. Project No.
7207

3. Recipient's Catalogue No.

4. Title and Subtitle
AN OVERVIEW OF AVAILABLE AND DEVELOPING
HIGHWAY VEHICLE ELECTRONIC TECHNOLOGIES

5. Publication Date
March 1990

6. Performing Organization Document No.

7. Author(s) Jouko A Parviainen, in co-operation with
John L Webster, Andrew B Levy et al,
Alison M Smiley, Robert L French

8. Transport Canada File No.
D 1465-529

9. Performing Organization Name and Address
Parviainen & Associates
1125 Linbrook Road
Oakville, Ontario, Canada L6J 2L3
Tel: (416) 849-5806
Fax: (416) 844-9945

10. DSS File No.
16SD.T8200-8-8543

11. DSS or Transport Canada Contract No.
16SD.T8200-8-8543/01-SD

12. Sponsoring Agency Name and Address

Transportation Development Centre
200 Rene Levesque Boulevard
West Tower - Suite 601
Montreal, Quebec
Canada H2Z 1X4

Ministry of Transportation Ontario
1201 Wilson Avenue
Downsview, Ontario
Canada M3M 1J8

13. Type of Publication and Period Covered
Final

14. Project Officer
Lewis R Sabounghi (TDC)
E. Ryerson Case (MTO)

15. Supplementary Notes (Funding programs, titles of related publications, etc.)
see also "Mobile Information Systems Impact Study"
TP 9360E (Transport Canada), TDS-88-07 (MTO), August 1988.

16. Abstract

The report presents a review of the state-of-the-art of automatic fleet monitoring, vehicular monitoring/control and travel support systems, and a brief update on navigation systems.

The report covers several well-established fleet monitoring technologies: automatic vehicle identification, classification, location, and monitoring, and weigh-in-motion. Image processing systems are also discussed. The section on on-board monitoring/control technologies focuses on the increasing sophistication of power train, chassis, auxiliary, driver interface, and feedback control systems. Travel support systems are divided into three groups: traffic information broadcasting, trip planning, and entertainment/communication systems. An update on vehicle navigation systems is presented in matrix format.

Functional diagrams and lists of known equipment suppliers are included. Application examples are also presented, such as the Heavy Vehicle Electronic Licence Plate Program, which is designed to increase the long-haul trucking industry's productivity and make road safety related enforcement more effective. Discussion on market perspectives covers recent technology developments and survey results indicating customer preferences on vehicle electronics.

The report highlights the need for an integrated intelligent system. It recommends that all systems intended to support navigation, maneuvering and control tasks receive a full human factors evaluation covering physical, perceptual, cognitive and motivational abilities and limitations. It recommends the establishment of a Canadian intelligent vehicle-highway system program to increase transportation productivity, equity and road safety, to help conserve resources and improve air quality, and to make travel more predictable and enjoyable.

17. Key Words
automatic fleet monitoring, vehicular monitoring and control, travel support systems, navigation, route guidance, mobile communication, on-board electronics, human factors

18. Distribution Statement
Report available from:
Ministry of Transportation Ontario, and
Transportation Development Centre (Transport Canada)

19. Security Classification (of this publication)
Unclassified

20. Security Classification (of this page)
Unclassified

21. Declassification (date)
-

22. No. of Pages
xxviii,202, App.

23. Price
-

Canada

Transports Canada Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. N° de la publication de Transports Canada **TP 10473E**	2. N° de l'étude 7207	3. N° de catalogue du destinataire

4. Titre et sous-titre

AN OVERVIEW OF AVAILABLE AND DEVELOPING
HIGHWAY VEHICLE ELECTRONIC TECHNOLOGIES

5. Date de la publication

juillet 1990

6. N° du document de l'organisme exécutant

7. Auteur(s)

Jouko A. Parviainen, avec John L. Webster, Andrew B. Levy et al,
Alison M. Smiley, Robert L. French

8. N° de dossier — Transports Canada

D 1465-529

9. Nom et adresse de l'organisme exécutant

Parviainen & Associates
1125 Linbrook Road
Oakville (Ontario)
L6J 2L3

10 N° de dossier — ASC

16SD.T8200-8-8543

11. N° de contrat — ASC ou Transports Canada

16SD.T8200-8-8543/01-SD

12. Nom et adresse de l'organisme parrain

Centre de développement des transports (CDT)
200 ouest, boul. René-Lévesque
Tour ouest, suite 601
Montréal (Québec) H2Z 1X4

Ministère des transports
de l'Ontario
1201, ave. Wilson
Downsview (Ontario)
M3M 1J8

13. Genre de publication et période visée

final

14. Agent de projet

Lewis R. Sabounghi (CDT)
E. Ryerson Case (MTO)

15. Remarques additionnelles (Programmes de financement, titres de publications connexes, etc.)

Voir également "Mobile Information Systems Impact Study", TP 9360E (Transports Canada), TDG-89-07 (MTO) août 1988.

16. Résumé

Le présent rapport fait un tour d'horizon des techniques utilisées pour la gestion des parcs roulants, les contrôles et les suivis routiers et l'information routière, et actualise brièvement les connaissances touchant les systèmes de navigation.

Il traite de plusieurs technologies parmi celles couramment utilisées pour l'identification, la classification, la localisation et le contrôle automatiques de véhicules et pour le pesage dynamique, ainsi que des systèmes d'imagerie active. Dans la partie sur l'électronique embarquée, il traite des systèmes de plus en plus avancés pour la régulation de la chaîne cinématique, de la dynamique de marche, des organes auxiliaires, de l'interface véhicule-conducteur et de la boucle de rétroaction. Pour ce qui est des systèmes d'information routière, il distingue entre diffusion de l'information, préparation des déplacements et communications/loisirs et dresse sous forme matricielle un tableau des différents systèmes de navigation routière.

En plus de présenter des schémas de principe, il dresse des listes de fournisseurs et donne des exemples d'applications, notamment le programme HELP ou plaque d'immatriculation électronique pour poids lourds, qui vise à accroître la productivité du camionnage grandes distances tout en contribuant à une sécurité routière accrue. Il traite des perspectives commerciales qui attendent les systèmes d'introduction récente et donne les résultats de sondages montrant où vont les choix en matière d'électronique embarquée.

Après avoir souligné la nécessité d'un système intégré intelligent, il propose que toutes les aides envisagées ou existantes (navigation, régulation ou manoeuvre) soient soumises à une évaluation ergonomique des plus rigoureuses, touchant toute la gamme des aptitudes physiques, mentales, perceptuelles, cognitives et motivationelles de l'opérateur. Enfin, il recommande que soit instauré au Canada un programme touchant les systèmes de coopération véhicule-voie visant à accroître la productivité et la sécurité des transports, à valoriser le réseau, à économiser l'énergie, à améliorer la qualité de l'air et à rendre les déplacements plus sûrs et plus agréables.

17. Mots clés

Gestion automatique des parcs roulants, contrôles et suivis routiers, information routière, navigation et cartographie routières, radiocommunications mobiles, électronique embarquée, ergonomie.

18. Diffusion

S'adresser au ministère des Transports de l'Ontario ou au Centre de développement des transports, Transports Canada.

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Déclassification (date)	22. Nombre de pages	23. Prix
Non classifiée	Non classifiée	--	xxxiv,202 et annexes	--

CDT/TDC 79-005
Rev 88

Canada

TDS-90-01 (MTO)
TP 10473E (TDC)

An Overview of Available and Developing Highway Vehicle Electronic Technologies

Prepared by:
Jouko A. Parviainen, Parviainen & Associates

Prepared for:
E. Ryerson Case
Traffic and Decision Systems Office
Transportation Technology and Energy Branch
Ministry of Transportation, Ontario

and

Lewis R. Saboungh
Transportation Development Centre
Policy and Coordination Group
Transport Canada

Published by:
Transportation Technology and Energy Branch
Ontario Ministry of Transportation

Published without prejudice as to the application of the findings. Crown copyright reserved; however, this document may be reproduced for non-commercial purposes with attribution to the ministry.

For additional copies, write:
Technical Publications (TT&E)
Ontario Ministry of Transportation
Room 321, Central Building
1201 Wilson Avenue
Downsview, Ontario
Canada M3M 1J8
(416) 235-3466

October 1990

CONTENTS

PAGE

ACKNOWLEDGEMENTS xiii

EXECUTIVE SUMMARY xv

SOMMAIRE xix

1 INTRODUCTION 1
1.1 Background 1
1.2 Objectives 1
1.3 Automatic Fleet Monitoring Systems 2
  1.3.1 Automatic Vehicle Identification 2
  1.3.2 Weigh-in-Motion 2
  1.3.3 Automatic Vehicle Classification 3
  1.3.4 Automatic Vehicle Location 3
  1.3.5 Automatic Vehicle Monitoring 4
  1.3.6 Image Processing Systems 5
1.4 Vehicle Dynamics 5
  1.4.1 Obeying the Laws of Physics 5
  1.4.2 Sample Resolutions 7
1.5 Travel Support Systems 8

2 STATE-OF-THE-ART REVIEW 9
2.1 Automatic Fleet Monitoring Systems 9
  2.1.1 Automatic Vehicle Identification 9
    a) Optical and Infrared Systems 9
    b) Inductive Loop Systems 11
    c) Radio Frequency and Microwave Systems 12
    d) Surface Acoustic Wave Systems 12
  2.1.2 Weigh-in-Motion 13
    a) Bending Plate Systems 13
    b) Capacitive Systems 13
    c) Shallow Weighscales 13
    d) Deep-pit Weighscales 15
    e) Bridge Weighing System 15
    f) Piezo-Electric Axle Load Sensors 15
  2.1.3 Automatic Vehicle Classification 16
    a) Presence Sensors 16
    b) Axle Sensors 18
    c) Combinations of Presence and Axle sensors 19
  2.1.4 Automatic Vehicle Location 19
    a) Dead Reckoning Systems 19
    b) Map-matching Augmentation 21

CONTENTS (cont'd)

PAGE

- c) Proximity Beacon Systems 22
- d) Cellular Telephone/Radio Communications Systems 22
- e) Radio Determination Systems 23
- f) Satellite-based AVL Systems 23

2.1.5 Automatic Vehicle Monitoring 25
- a) Introduction 25
- b) Electronic Tachographs 25
- c) Taximeters 27
- d) On-board Computers 27

2.1.6 Image Processing Systems 28

2.2 Vehicular Monitoring and Control 37

2.2.1 Introduction 37

2.2.2 Power Train Control Systems 38
- a) Engine Control 38
- b) Transmission Control 40
- c) 4-Wheel Drive 43

2.2.3 Chassis Systems 43
- a) Braking 43
- b) Suspension 46
- c) Steering 46

2.2.4 Auxiliary Systems 49
- a) External Lighting Controls 49
- b) Window Controls 50
- c) Vision Enhancement 50
- d) Occupant Safety Restraints 51
- e) Electrical Power 52
- f) Individualized Comfort and Convenience 53
- g) Diagnostics and Service Memory 54
- h) Security Systems 55

2.2.5 Driver Interfaces 55

2.2.6 Feedback Control Systems 59
- a) Basic Servo Loop 59
- b) Digital Microcomputer Position Control 59
- c) Individual Subsystems 62
- d) Centralized Control 62
- e) Hierarchical Control 65

2.3 Travel Support Systems 70

2.3.1 Traffic Information Broadcasting Systems 70
- a) Introduction 70
- b) Highway Advisory Radio 70
- c) Automatic Highway Advisory Radio 73
- d) Autofahrer Rundfunk Information 73

CONTENTS (cont'd)

PAGE

        e) ARI with Actual Measurement 74
        f) Radio Data System 75
    2.3.2 Trip Planning Services 80
        a) Introduction 80
        b) TELETEL 80
        c) ATIS 81
        d) Computrip 81
    2.3.3 Entertainment/Communication Systems 82
        a) Sound Systems 82
        b) Two-way Communication Systems 82
        c) Office Systems 83
        d) Video Systems 84
        e) Closing Thoughts 84
2.4 Vehicle Navigation and Route Guidance Systems 84
    2.4.1 Introduction 84
    2.4.2 System Characteristics 85
    2.4.3 Features and Specifications of Existing Systems 86

3 HUMAN FACTORS CONSIDERATIONS 90
3.1 The Driving Task 90
3.2 Driver Characteristics 90
    3.2.1 Introduction 90
    3.2.2 Mental Workload 91
    3.2.3 Driver Training on Support Systems 96
    3.2.4 Driver Acceptance 97
3.3 Effect of New Technology on Driver Performance 99
    3.3.1 Automatic Fleet Monitoring Systems 99
    3.3.2 Vehicular Monitoring and Control Systems 99
    3.3.3 Travel Support Systems 101
    3.3.4 Vehicle Navigation and Route Guidance Systems 101
3.4 Need for an Integrated Intelligent System 102
3.5 Evaluation 105
3.6 Conclusions 107

4 MARKET PERSPECTIVE 109
4.1 Automatic Fleet Monitoring Systems 109
    4.1.1 Introduction 109
    4.1.2 Heavy Vehicle Monitoring and Management Systems 109
    4.1.3 Further Market Considerations 111
4.2 Vehicular Monitoring and Control Systems 118
    4.2.1 Selected Features, Applications and Specs 118

CONTENTS (cont'd)

PAGE

a) Engine ... 118
b) Transaxle ... 119
c) Braking ... 121
d) Driver Information Systems ... 127
4.2.2 New Technologies ... 128
a) Computers and Processors ... 128
b) Expert Systems ... 129
c) Sensors ... 130
d) Diodes ... 131
e) New Displays ... 131
f) Engine Technology ... 133
g) Suspension Technology ... 134
4.2.3 Market Considerations ... 136
a) Introduction ... 136
b) Selected Survey Results ... 137
4.3 Travel Support Systems ... 137
4.3.1 GM Mobile Information System ... 141
4.3.2 Bosch Board Information Terminal ... 144
4.3.3 Implications ... 149

5 INTERNATIONAL PROGRAM ... 150
5.1 Europe ... 150
5.1.1 DRIVE ... 150
5.1.2 EUREKA ... 153
a) Prometheus ... 154
b) EUROPOLIS ... 156
c) CARMINAT ... 156
d) ATIS ... 156
e) ERTIS ... 156
f) DAB ... 157
g) DEMETER ... 157
5.2 Japan ... 157
5.2.1 AMTICS ... 157
5.2.2 RACS ... 161
5.3 North America ... 165
5.3.1 HELP ... 165
5.3.2 AWACS ... 171
5.3.3 Virginia Fastoll Project ... 171
5.3.4 Other Electronic Toll Collection Projects ... 172
a) Coronado Bridge, San Diego ... 172
b) North Dallas, Tollway, Texas ... 175
c) New Orleans Bridge, Louisiana ... 175
5.3.5 TravTek ... 175

CONTENTS (cont'd)

PAGE

5.4 Canadian Projects 175
  5.4.1 Transport Canada Projects 175
    a)Potential of Emerging Technologies on Future Navigation Systems in the Canadian Transportation Sector 175
    b) Needs and Opportunities for Motor Vehicle Safety and Productivity R&D in Canada 176
    c) Other Related Studies 176
  5.4.2 Provincial Projects 176
5.5 Remarks on Government Regulatory Role 177

6 CONCLUDING REMARKS 181

REFERENCES 183

BIBLIOGRAPHY 185

APPENDICES

A AUTOMATIC FLEET LOCATION/MONITORING SYSTEMS
Brief History

B MISIS – SELECTED EXHIBITS
(Mobile Information Systems Impact Study)

FUTURE MOBILE INFORMATION SYSTEMS
A Functional Block Diagram

ELECTRONIC DISPLAY DESIGN GUIDE

APPLICATIONS
Travel Advisory
Fleet Management
Traffic Management
Mobile Office
Occupant Activity
Vehicle/Driver Monitoring and Control

C AUTOMOTIVE ELECTRONICS – Sample Diagrams

D AUTOMOTIVE ELECTRONICS – Sample Specifications

E UNITED STATES IVHS PROGRAM – Suggested Milestones
Mobility 2000 Workshop (9-21 March 1990, Dallas, Texas)

CONTENTS (cont'd)

F CONTACT LIST: AVI / WIM / AVC / AVL / IPS / TPS

G CANADIAN AVI AND WIM EQUIPMENT
Sample Specifications

H TRAVTEK – Press Release

EXHIBITS

PAGE

1 AUTOMATIC VEHICLE IDENTIFICATION – System Diagrams 10
2 WEIGH-IN-MOTION – System Diagrams 14
3 AUTOMATIC VEHICLE CLASSIFICATION – System Diagrams 17
4 AUTOMATIC VEHICLE LOCATION – System Diagram 20
5 AUTOMATIC VEHICLE MONITORING – System Diagram 26
6 IMAGE PROCESSING – System Diagram 30
7 AUTOMATIC VEHICLE IDENTIFICATION SYSTEMS 31
8.a PERMANENT WEIGH-IN-MOTION (WIM) – Piezo-electric Cable Systems 32
8.b PERMANENT WEIGH-IN-MOTION (WIM) – In-pavement Pit Systems 33
8.c PORTABLE WEIGH-IN-MOTION (WIM) – Capacitive Weighmat Systems 34
8.d OTHER WEIGH-IN-MOTION SYSTEMS 34
9.a AUTOMATIC VEHICLE LOCATION SYSTEMS – Ground-based AVL Systems 35
9.b AUTOMATIC VEHICLE LOCATION SYSTEMS – Satellite-based AVL Systems 35
10 IMAGE PROCESSING SYSTEMS 36
11 MULTI-POINT FUEL INJECTION 39
12 CHRYSLER ENGINE CONTROL COMPUTER 41
13 ELECTRONIC TRANSAXLE CONTROL SYSTEM DIAGRAM 42
14 BRAKING FORCE, TRACTION AND SIDE FORCE VERSUS SLIP 44
15 ANTI-LOCK BRAKE CONTROL SYSTEM COMPUTER 45
16.a ACTIVE SUSPENSION SYSTEM 47
16.b ACTIVE SUSPENSION SYSTEM – Hydraulic Diagram 48
17 OLDSMOBILE DRIVER INFORMATION SYSTEM MODULE 57
18.a BASIC POSITION CONTROL SERVO LOOP SYSTEM 60
18.b DIGITAL MICROCOMPUTER POSITION CONTROL SYSTEM 61
19.a TOTAL DECENTRALIZATION 63
19.b CENTRALIZED CONTROL 64
19.c HIERARCHICAL CONTROL 66
20.a VEHICLE MONITORING AND CONTROL – Not Related to Motion 67
20.b INTEGRATED VEHICLE CONTROL – Related to Motion 68
21 ELECTRONICS IN THE CAR 69
22 TRAFFIC INFORMATION BROADCASTING – System Diagram 71
23 STRUCTURE OF RDS SEQUENCES 76
24 PROPOSED RDS TYPE 8 GROUP CONTENT 77
25 TYPICAL MESSAGE CATEGORIES AT OPERATOR TERMINAL 78
26 TRIP PLANNING SERVICES – System Diagram 79
27 VEHICLE NAVIGATION/ROUTE GUIDANCE SYSTEMS – Current Features 88
28 INFORMATION NEEDS AND HUMAN LIMITATIONS TO BE CONSIDERED IN THE APPLICATION OF HIGH TECHNOLOGY IN VEHICLES 92
29 RANGE OF DRIVER, VEHICLE AND ENVIRONMENT CHARACTERISTICS TO BE CONSIDERED IN DESIGN, TESTING AND OPERATION 93
30 POTENTIAL USERS AND APPLICATION OF HEAVY VEHICLE MONITORING INFORMATION 110

EXHIBITS (cont'd)

PAGE

31 PRIMARY BENEFITS OF MOBILE IN FORMATION SYSTEMS IN THEIR MAJOR APPLICATION AREAS 113
32 COMPONENTS OF TRAVEL DEMAND – Passenger and Freight Transportation Sectors 115
33 TRUCK TRANSPORTATION – Factors Affecting Productivity 117
34 VEHICLE MONITORING INFORMATION MOST DESIRED 138
35 CONTINUOUSLY DISPLAYED INFORMATION – GM Employee Survey 139
36 INFORMATION NOT CONTINUOUSLY AVAILABLE – GM Employee Survey 140
37 GM MOBILE INFORMATION SYSTEM 142
38 BOARD INFORMATION TERMINAL DEMONSTRATION UNIT 145
39 BIT FUNCTIONAL GROUPINGS 146
40.a BOARD INFORMATION TERMINAL – Communication Systems 147
40.b BOARD INFORMATION TERMINAL – On-board Systems 148
41 DRIVE PROJECT AREAS 151
42 PROMETHEUS ORGANIZATION 155
43.a AMTICS CONCEPT 158
43.b AMTICS – Information Provisions and Range 159
43.c AMTICS –Typical Car-Mounted Unit 160
44.a RACS CONCEPT 162
44.b RACS – Features of an Intermittent, Minimum Zone System 163
44.c RACS – Facilities Used in Comprehensive System Test 164
45.a HELP SYSTEM DEVELOPMENT PROGRAM 166
45.b PLANNED CRESCENT INSTALLATIONS 169
45.c CRESCENT APPLICATIONS 170
46.a FASTOLL SYSTEM DESIGN 173
46.b FASTOLL EQUIPMENT LAYOUT 174

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the guidance and assistance provided by members of the Steering Committee:

Ministry of Transportation Ontario

E.R. Case (Chairman)	(Rye)	Traffic and Decision Systems Office Transportation Technology and Energy Branch
P.L. Bank	(Penny)	Motor Carrier Policy Office
J. Dion	(Joseph)	Transportation Regulation Development Branch
D. Davis	(Don)	Transit Office Municipal Transportation Division
J.D. Duncan	(Dave)	Municipal Transportation Policy Office Municipal Transportation Division
F.D. Harris	(Fred)	Traffic Management and Engineering Office Highway Operations and Maintenance Division
M.H. Perera	(Max)	Highway Capital Administration Office Transportation Capital Branch
A. Roldan	(Tony)	Provincial Transportation Systems Office Provincial Transportation Program
J. Tsai	(Joe)	Transit Control Technology and Systems Office Transportation Technology and Energy Branch

Ministry of Culture and Communications

L.R.F.A. Gomes	(Lamberto)	Operations and Technology Office Communications Division

Transport Canada

R.N. Sabounghi (Co-Chairman)	(Lewis)	Technology Applications Division Transportation Development Centre

Our special thanks to:

- Arjan Chandan of Transport Canada for briefing the Steering Committee on the status of Transport Canada projects;

- Pierre La Fontaine of Quebec Ministry of Transport for providing detailed notes from Mobility 2000 sessions in Dallas (19-21 March 1990).

EXECUTIVE SUMMARY

The forerunner to this project, the *Mobile Information Systems Impact Study* (report number TP 9360E, TDS-88-07), presented a state-of-the-art review on devices which can display a vehicle's position relative to a map data base and which support navigation or route guidance functions. This Highway Vehicle Electronics project was initiated to review the complementary technologies of automatic fleet monitoring systems, vehicular monitoring/control systems and travel support systems, and to present an update on navigation systems.

This report is intended to provide a technology primer on these systems and their applications. The two reports together establish a knowledge platform for reviewing critical issues in the development of on-board electronic technology toward increasing the safety and productivity of the road transport system. The methodology employed consisted of literature reviews, and of brain-storming sessions on the potential applications for the technologies.

Several fleet monitoring systems are already well established, namely automatic vehicle identification (AVI), classification (AVC), location (AVL), monitoring (AVM), and weigh-in-motion (WIM). Image processing systems – today still in their infancy – will in the future offer a useful complement to the other technologies.

Individually, and in combination, these technologies present exciting opportunities. A prime example is HELP, or Heavy Vehicle Electronic Licence Plate Program, which will increase the productivity of the long-haul trucking industry by eliminating time-consuming stops at every weighscale. It will also make enforcement of axle weight, hazardous cargo, mechanical fitness, and maximum driving hours regulations more efficient – thereby contributing to increased road safety.

Two demonstrations of vehicle navigation/route guidance systems in Europe – Berlin and London – rely entirely on road-side communication using infrared beacons. But elsewhere, autonomous in-vehicle units, using dead-reckoning navigation with map-matching, are gaining momentum. The primary reasons for this trend are that the government agencies are not yet providing any support systems, the launching of GPS satellites has been delayed, and many of the features that will really help market penetration (e.g., environmental databases) are in fact not dependent on a real-time, road-side system.

While true on-board travel support systems are still in their infancy, there are no technological barriers hindering their development. For the time being, however, they will have to be autonomous. They will not be able to connect interactively to travel-related services – for example, to allow on-screen comparison of available accommodations en route to a community – as these services are not yet provided.

While there are some interesting experimental systems, and a demonstration is about to start in Orlando, Florida, the time for a "mobile videotex service that will also navigate" has not yet arrived.

The potential markets for systems that incorporate all or some of the above functional capabilities will be truly vast. Carriers will try to increase the productivity of their operations, and families and individuals will try to make commuting travel less onerous and leisure travel full of discovery. Canadian urban and intercity transport systems must take early advantage of all possible productivity increases in order for us to stay competitive. Any waste in transport, compared to other countries, will surface in the final price of the products, making them less competitive. Within the transport sector itself, Canadian carriers cannot remain competitive unless they equip their fleets and have access to mobile communication, inter-active route guidance, and Electronic Data Interchange services – at a level equal to the U.S. carriers.

Beyond the basic objectives of the direct users, however, the primary motivation for implementing mobile information systems will be societal: increased road safety, conservation of resources, environmental protection, and increased equity.
Indirect users such as municipal and provincial traffic control centres, which benefit from the information available from vehicles equipped with on-board devices, will play a major role in market developments. They will be able to collect traffic data to assist in real-time traffic management and enhanced traffic information broadcasting. The agencies will be able to control or charge for access to certain downtown areas or incoming corridor facilities during peak congested periods, monitor hazardous product shipments, or just enforce the rules of the road.

It may be that the installation of AVI transponder units will have to be made mandatory by legislation – to facilitate the implementation of many transportation demand management (TDM) measures which have been too impractical to implement in the past. Such AVI legislation would have to be paralleled by wide-scale installation of in-pavement and road-side interrogator units and data accumulators, and the required communication links to the traffic management centre.

In the view of many, an electronics-based strategy for the road transport sector is bound to prove highly cost-effective – and complementary to optimizing any subsequent capacity investments. In Europe, the application of in-vehicle/road-side electronics will be the next frontier in implementing "traffic calming" (i.e., travel demand management) – in the minds of many Europeans, the last chance to overcome the "fatal attraction" of the automobile.

Electronic vehicular monitoring and control systems came into being in American and Canadian production passenger cars during the mid-seventies as the result of two factors: the federal legislation (U.S.) of exhaust emissions and fuel economy, and the concurrent evolution of large-scale integrated circuit microprocessors. Now the use of on-board electronics is accelerating. According to the recent Delphi V study (by University of Michigan), the share of automobiles equipped with electronic transaxle, anti-lock brakes, traction control, multiplexing and active suspension will all double from 1995 expected levels by the year 2000 – amounting to some 15-20% of vehicle production costs. Already the total electronics content of an average American/ Canadian-built passenger car has increased from the $50 AM radio in the early 1960s to some $900 today.

In terms of increased road safety, however, the impact of all this electronic wizardry is not yet apparent; the annual carnage on our road system continues. There is a definite need for additional systems to assist drivers in complex driving situations. Sophisticated computers and sensors will be required to perform analysis of real-time vehicle dynamics and to intervene with warnings or overt action when a driver is approaching limits of safety for existing operating conditions.

Active suspension control, integrated chassis control systems and full multiplexing are being introduced in top-line automobiles. Microwave and solid-state laser radar systems are being investigated for use with electronic cruise control systems to provide an automatic safe separation distance from the car in front. Most sophisticated adaptive control systems will require reliable real-time diagnostic monitoring. With proper design they can compensate for manufacturing tolerances, real-time variations in operating conditions, and degrading due to aging.

Other, less glamorous, electronics-driven functions can also increase road safety. With the help of automatic service-due advisories and expected-failure warnings, and with warnings for low tire air pressure and fluid levels, the average operating condition of vehicles on the road can be substantially improved. Driver performance monitoring, which triggers a snooze or a night-vision failure alert, can further contribute to road safety.

While there are many (technical) countermeasures against problems rising from increasing electronic complexity, there are no shortcuts or technological fixes for the most critical element in the driver/vehicle/road system: the human factor. Clearly, offering a driver support in the navigation, manoeuvring and control tasks has the potential to increase safety and efficiency. However, there is also the potential to overload the driver with information, thereby increasing the mental workload and decreasing the amount of attention that can be paid to the primary driving tasks.

Adding a support system will change the driving task in unforeseen ways. Fleet monitoring systems that are designed to collect data unobtrusively will interfere with driving the least. On the other hand, navigation systems – which divert the driver's attention away from the manoeuvring and control of the vehicle – are likely to interfere considerably with the primary driving tasks.

There is nothing to prevent a driver from overloading himself and potentially compromising safety; for example, by using a navigation system, talking on a cellular phone and checking on moment-to-moment gas economy. Current support systems do not select or integrate information according to the demands of the driving tasks or according to the state of the driver. For this reason, there is a need for an integrated intelligent system which can prioritize warnings and override auxiliary functions if necessary. For all support systems, it is vital that designs receive a full human factors evaluation covering physical, perceptual, cognitive and motivational abilities and limitations.

The pace of technical, organizational and transport-political innovation is very fast in Europe and Japan. The momentum in research and demonstration of in-vehicle electronic technologies is, if anything, increasing. Major long term financial commitments have been made by the governments, and the automobile and electronics industries. Universities and other research facilities are heavily involved.

The reasons have not changed. Application of micro-electronics to the road transport system is seen as an urgent necessity – not only as a way to improve road safety and reduce or better manage traffic congestion, but for environmental reasons. And the industrial opportunities open to countries willing to invest in the early development work are considered very significant.

This has been recognized in the United States. The U.S. Department of Transportation has proposed to the Congress a "national cooperative effort to foster the development, demonstration and deployment of Intelligent Vehicle-Highway System (IVHS) technologies." The program will consist of Advanced Traffic Management Systems (ATMS), Advanced Driver Information Systems (ADIS), Advanced Vehicle Control Systems (AVCS), and Commercial Vehicle Operations (CVO). Major research projects are already underway in California, Michigan, and other states.

There is no question that Canada must establish its own IVHS program to safeguard its own interests and to ensure that we do not fall behind in a critical high technology/applications research area. Only from the strength of our own program can we hope to fully benefit from the cooperative research and development opportunities that are available now and that will arise in the future. Where Canada already has access to foreign programs, these opportunities should be promptly exploited through cooperative research and joint ventures. There is an urgent need to establish an active Canadian technology strategy in the whole IVHS area.

SOMMAIRE

Le travail de recherche antérieur "Mobile Information Systems Impact Study" TP 9360E a recensé les systèmes de communication mobiles actuels capables d'afficher en tout moment la position d'un véhicule sur une carte et d'exécuter certaines fonctions de navigation ou de cartographie routière. La présente recherche sur l'électronique embarquée visait à recenser les technologies complémentaires telles que gestion automatisée des parcs roulants, contrôles routiers, aides à la conduite et information routière, en plus d'actualiser les connaissances sur les systèmes de navigation.

Grâce au présent rapport qui fait un tour d'horizon de tous ces systèmes et de leurs applications, et au rapport précédent sur les systèmes de communication mobiles, il devient possible de dégager les grandes tendances dans l'évolution de l'électronique embarquée, et d'en évaluer les applications pour une sécurité et une productivité accrues du réseau routier. Des recherches documentaires ont été faites, complétées par des séances de remue-méninges sur les applications possibles de toutes ces technologies.

Dans le domaine de la gestion des parcs roulants, certaines technologies sont maintenant au point : identification, classification et localisation automatiques de véhicules, contrôles routiers et pesage dynamique. La technologie de l'imagerie active, encore émergente, ne manguera pas dans un proche avenir d'apporter un complément fort utile.

Ensemble ou séparément, ces technologies sont très prometteuses. Citons, à titre d'exemple, le programme HELP (plaque d'immatriculation électronique pour véhicules lourds) qui, en évitant aux poids lourds effectuant de longs trajets d'avoir à s'arrêter à toutes les stations de pesage, accroît la productivité de ce secteur du camionnage. Ce programme contribue également à la sécurité routière en rendant les contrôles routiers (charges à l'essieu, marchandises dangereuses, état mécanique et nombre d'heures de conduite) plus rapides et plus efficaces.

A Berlin et à Londres, deux systèmes de navigation et de cartographie routières comportant des émetteurs-récepteurs infrarouges latéraux (c'est-à-dire en bordure de la route) ont été mis en exploitation expérimentale. Ailleurs, c'est la navigation à l'estime complétée d'un système autonome de repérage sur carte qui semble devoir l'emporter, pour la simple raison que les systèmes de soutien ne sont pas encore en place, les satellites GPS, par exemple, et que nombre des éléments qui pourraient réellement faciliter l'introduction de systèmes interactifs sur le marché tels que les bases de données environnementales ne nécessitent pas l'implantation de systèmes latéraux fonctionnant en temps réel.

Les systèmes d'information routière embarqués, bien qu'ils en soient à leurs débuts, devraient connaître un développement rapide, du fait de l'absence de verrous technologiques. Mais il ne pourra s'agir d'abord que de systèmes autonomes, faute de serveurs d'information de voyage que l'on peut interroger par exemple sur les diverses possibilités de logement le long du trajet suivi. Malgré certaines expérimentations en cours et l'introduction imminente d'un système expérimental à Orlando (Floride), le temps d'un vidéotex mobile doté de fonctions de navigation n'est pas encore venu.

Le marché que pourra occuper un système doté de toutes ou de quelques-unes des fonctionnalités décrites sera énorme. Les transporteurs voudront accroître leur productivité et les particuliers rendre leurs déplacements soit plus économiques, soit plus agréables selon qu'il s'agit de travail ou de loisirs. Les réseaux de transport urbain ou interurbain canadiens doivent tirer très vite profit de tout accroissement de la productivité afin de pouvoir soutenir la concurrence. Tout retard technologique dans le domaine des transports risque de se répercuter sur les prix et les rendre moins compétitifs au niveau international. Les transporteurs canadiens ne pourront demeurer dans la course que si leurs parcs roulants sont aussi bien équipés que ceux de leurs concurrents américains, avec des systèmes mobiles et interactifs de communication et de guidage, et des moyens pour l'échange de données informatisées.

Outre les objectifs immédiats des principaux intéressés, ce sont des objectifs de nature sociale qui motiveront l'adoption des systèmes de communication mobiles : sécurité accrue, économie des ressources naturelles, protection de l'environnement et valorisation du réseau.

L'évolution de ces systèmes sera également infléchie par les utilisateurs indirects, les municipalités et les responsables provinciaux de la gestion du trafic, par exemple, qui voudront tirer parti des informations recueillies grâce aux systèmes embarqués. Ils pourront les utiliser pour une gestion du trafic en temps réel et pour rendre les comptes rendus radiophoniques sur l'état du trafic plus actuelles. Ils pourront également s'en servir pour réguler et peut-être aussi taxer l'accès à certains secteurs de la ville ou à certaines voies menant à la ville durant les heures de pointe, pour surveiller les livraisons de marchandises dangereuses ou pour simplement appliquer le Code de la route.

Il se peut que l'implantation de transpondeurs pour l'identification automatique de véhicules soit imposée par voie législative, afin de permettre l'application de plusieurs des dispositions relatives à une stratégie de gestion de la demande de transports, restées inopérantes jusqu'ici faute d'infrastructure telle que capteurs latéraux ou noyés dans la chaussée, centralisateurs de données et liaisons avec les organes centraux de gestion du trafic, et dont l'implantation devra elle aussi faire l'objet de mesures semblables.

Convertir le réseau routier à l'électronique serait, d'après plusieurs spécialistes, non seulement éminemment rentable, mais nécessaire à l'optimisation des aménagements futurs visant à accroître la capacité de l'infrastructure routière. C'est d'ailleurs ce à quoi se préparent les Européens engagés dans une "bataille" désespérée contre l'envahissement de l'automobile, et pour qui une gestion rationnelle des transports serait l'arme ultime contre ses multiples attraits.

Les systèmes de suivi et de commande électroniques dont sont équipés les voitures de tourisme fabriquées au Canada et aux Etats-Unis depuis le milieu des années 1970 doivent leur existence à la conjugaison de deux facteurs : la loi adoptée aux Etats-Unis sur la réduction des émissions polluantes et sur l'économie de carburant, et le développement des circuits à grande échelle d'intégration. Depuis, l'électronique embarquée a fait beaucoup de progrès. Selon une étude récente faite par l'Université du Michigan selon la méthode Delphi V, la proportion de voitures équipées d'une boîte-pont électronique, de freins antiblocage, d'une régulation de la traction, d'un multiplexage du câblage et d'une suspension active aura doublé d'ici l'an 2000, par rapport aux prévisions pour 1995, et que l'électronique embarqué entrera pour 15 à 20 p. 100 du coût total de fabrication. Déjà, le cout de l'électronique équipant une voiture de prix moyen de fabrication américaine ou canadienne a passé des 50 $ que coûtait une radio AM au début des années 1960 à quelque 900 $ de nos jours.

Mais toutes ces merveilles électroniques ont-elles accru la sécurité routière? A voir les statistiques routières sur les décès, on ne le jurerait pas. Le conducteur moyen a réellement desoin d'auxiliaires susceptibles de l'aider à se sortir de conditions de circulation dangereuses. Exemple, un ordinateur et des capteurs servant à analyser de façon continue la dynamique de marche et capables d'intervenir soit indirectement par des avertissements, soit automatiquement dès que les limites d'une conduite sûre dans des circonstances données risquent d'être dépassées.

Les voitures haut de gamme commencent à être équipées d'une suspension active, d'une régulation électronique de la dynamique de marche, d'un multiplexage du câblage, tandis que sont à l'étude des dispositifs de télédétection permettant d'ajuster la vitesse de marche en fonction de la distance séparant la voiture de celle qui la précède, et utilisant soit le radar hyperfréquences, soit le radar laser à semiconducteurs. La plupart des systèmes adaptatifs les plus avancés doivent pouvoir compter sur des capteurs fiables afin que leurs diagonostics soient actuels. Bien conçus, ils peuvent compenser pour les tolérances de fabrication, les variations dans les conditions de fonctionnement et l'usure due à l'âge.

D'autres fonctionnalités électroniques sont peut-etre moins nobles mais tout aussi indispensables pace que axées sur la sécurité, ou parce qu'elles maintiennent la voiture dans un état de marche plus qu'adéquat. Elles lancent des messages d'alerte (pression d'air dans les pneus ou d'huile trop faible) ou de pré-alerte (intervention nécessaire ou panne possible), et elles alertent le conducteur en cas d'une baisse de vigilance ou de vision en conduite nocturne.

Tous ces dispositifs sophistiqués permettent de faire face à la complexité grandissante de l'électronique automobile, certes, mais ils ne peuvent pas grand chose contre l'élément le plus critique de tous dans la boucle conducteur/véhicule/chaussé : l'élément humain. S'ils concourent à la navigation, à la régulation ou à la manoeuvre, et s'ils contribuent à la sécurité et à la rentabilité, ils n'en risquent pas moins de surcharger le conducteur, d'accroître la charge mentale qui pèse sur lui et de le distraire de la tâche essentielle de conduire.

Un système d'information peut intervenir dans la tâche de conduire de la façon la plus imprévue. Alors qu'un dispositif pour la saisie de donnés sur la marche d'un véhicule lourd fonctionne discrètement, une aide à la navigation, par exemple, risque de distraire momentanément le conducteur et de le détourner de sa tâche principale qui est de conduire.

Un conducteur qui accepte d'être surchargé par des tâches auxiliaires telles que utiliser une aide à la navigation, parler au téléphone cellulaire ou vérifier la consommation, joue de son propre chef avec la sécurité. Les systèmes d'information routière actuels, lorsqu'ils interviennent, le font sans tenir compte des besoins du conducteur ou de sa charge mentale. D'où la nécessité d'un système intelligent capable de sélectionner, de hiérarchiser, voire d'élaguer, selon les circonstances. Et, quel que soit le système choisi, il devra avoir été soumis à une évaluation ergonomique des plus rigoureuses, touchant toute la gamme des aptitudes physiques, mentales, perceptuelles, cognitives et motivationnelles de l'opérateur.

L'allure à laquelle avance, en Europe et au Japon, l'innovation dans les domaines technique et organisationnel ainsi que dans les mesures institutionnelles est très rapide. Quant à la recherche et aux expérimentations sur l'électronique automobile, elles se dynamisent de plus en plus. Tant les gouvernements que les secteurs privés de l'automobile et de l'électronique ont consenti des engagements financiers à long terme considérables et font appel à la collaboration active des universités et autres établissements de recherche.

Pourquoi considère-t-on l'électronique et ses applications aux transports comme un besoin essentiel? Pour des raisons reliées à une sécurité routière accrue, à une gestion améliorée du trafic et à la protection de l'environnement, mais aussi à la conviction que plus on s'y engage tôt, plus les retombées industrielles seront considérables.

Les Etats-Unis partagent cette conviction, au point que le ministère des Transports de ce pays a proposé au Congrès que soit lancée une campagne nationale de recherches associatives sur le développement, la démonstration et la mise en service de systèmes intelligents de coopération véhicule-route, formée des éléments suivants : systèmes avancés de gestion du trafic, systèmes avancés d'information routière, aides à la conduite et gestion des opérations du camionnage. D'importants travaux de recherche ont d'ailleurs commencé dans certains Etats, comme la Californie, le Michigan, etc.

Il est indispensable que le Canada emboîte le pas, afin de veiller sur ses intèrêts propres et pour ne pas se retrouver à la traîne des autres pays dans un secteur de R&D aussi vital. C'est par la force d'un tel programme que le Canada pourra espérer tirer parti des créneaux de R&D associative qui s'ouvrent ou qui ne manqueront pas de s'ouvrir, tôt or tard. Lorsque le Canada est déjà partie prenante d'un programme lancé ailleurs, il faudrait qu'il saisisse toutes les occasions de recherche associative ou d'entreprise en coparticipation. Il faut donc que le Canada se dote au plus vite d'une stratégie touchant tout le domaine de la coopération véhicule-route.

1 INTRODUCTION

1.1 Background

The forerunner for this project, the *Mobile Information Systems Impact Study* [1],[1] focused on devices which can display vehicle position relative to a map data base and which facilitate or perform navigation or route guidance functions.

The MISIS report includes a review of the state-of-the-art of in-vehicle navigation and mobile communication technologies, and of components of representative systems and methods for digitizing and storing map data. It covers 39 systems, demonstrated or announced in the 1980s, classifying them by their infrastructure relationship, navigation technique and available functions, map format and storage, output/input methods and potential applications. The report includes an introduction to human factors considerations – covering the "human processor" concept, basic man-machine interface issues and presenting a guide for the design of in-vehicle display/control units.

A discussion on market perspectives includes an extensive list of possible applications for each of the primary system functions, and a brief description of the direct and indirect user communities and their primary system requirements. Selected highlights of national programs in Europe, Japan and North America are presented. The report highlights the importance of developing safety oriented standards and regulations and presents seven priority areas of research appropriate for developing a Canadian strategy.

1.2/ Objectives

The primary objective for this project is to complement the state-of-the-art review presented in the MISIS report: to focus on automatic fleet monitoring systems, on vehicular monitoring and control systems – and, albeit to a lesser extent, on travel support systems.

It is designed to provide a basic primer on these technologies and their applications, including automotive electronics in general – so that, together with the MISIS report, a platform will have been established from which to relate to the basic principles and issues in the introduction of on-board electronics toward increasing the safety and productivity of the road transport system.

---

1) Numbers in square brackets designate references at the end of the report. Additional related materials, not explicitly referenced, are listed in the bibliography.

1.3 Automatic Fleet Monitoring Systems

This first section provides an introduction to automatic fleet monitoring systems. It provides an overview and definitions of the following technologies:
- Automatic Vehicle Identification (AVI)
- Weigh-In-Motion (WIM)
- Automatic Vehicle Classification (AVC)
- Automatic Vehicle Location (AVL)
- Automatic Vehicle Monitoring (AVM)
- Image Processing Systems (IPS).

1.3.1 Automatic Vehicle Identification

Automatic vehicle identification (AVI) is the term used for techniques which uniquely identify vehicles as they pass specific points on the highway, without requiring any action by the driver or an observer. Automatic vehicle identification systems typically comprise three functional elements: a vehicle-mounted electronic transponder, encoded with a unique identification code; a roadside reader unit, with its associated antennas; and a system for the storage, analysis and transmission of data.

There are several approaches to AVI, which have been developed since the initial investigations were performed in the 1960s. These approaches can be broadly categorized into four technology areas:
- optical and infrared systems
- inductive loop systems
- radio frequency and microwave systems
- surface acoustic wave systems.

Each of those technological approaches will be detailed in the review section of this report.

1.3.2 Weigh-in-Motion

Weigh-in-Motion (WIM) is an established technology throughout the world. WIM systems are used to obtain the axle and gross weights of vehicles using in-pavement sensors while they are travelling along the highway. There is a wide variety of systems available, from slow-speed WIM through a range of full highway speed systems, each with a different level of capability and cost.

The possible alternatives for weigh-in-motion systems, which will be described in detail in the review section, include:

- bending plate systems
- shallow weighscale systems
- deep pit weighscales
- bridge systems
- capacitive systems
- piezo-electric systems.

1.3.3 Automatic Vehicle Classification

Automatic vehicle classification (AVC) systems are used to collect classified traffic data. AVC systems are installed in the highway to collect these data reliably, continuously and at low-cost. AVC systems comprise the following components:

1. sensors, which provide data on the presence or passage of the vehicle to be classified;

2. detectors, which receive signals from the sensors, and condition them, before passing them on to a processor;

3. the processor, which performs the basic calculation of vehicle length, number of axles, etc., from which vehicle class is determined; and

4. the recorder, which stores that data and manipulates it into the presentation format.

General requirements for sensors are that they be low-cost, easy to install and above all reliable. Several technologies are available which meet these requirements in specific applications. The last three components are normally combined in the roadside unit. The use of solid-state electronic components, with microprocessor control and CMOS memory data storage, has reduced design and reliability problems in these areas.

1.3.4 Automatic Vehicle Location

Automatic vehicle location (AVL) systems are used for providing vehicle location information to a central control, rather than to the driver. This enables vehicle fleet managers to monitor their resources and deploy them more efficiently. In particular, they allow the fleet manager to schedule complex trips with multiple destinations in real-time, as orders are received or circumstances change. This reduces excess mileage caused by vehicles making multiple single-destination trips.

The location technologies used as the basis of most AVL systems involve dead-reckoning, proximity device or radio determination. The computed location information is then displayed to personnel in the control centre either on a map display or as a coordinate listing. Fleet management software can also be utilized to manipulate the computed location data. (Brief history of AVLM developments is presented in Appendix A).

1.3.5 Automatic Vehicle Monitoring

Automatic vehicle monitoring (AVM) systems are a class of system which supplement AVL technologies with various in vehicle devices. These range from simple tachographs through taximeters to full computer-based management systems and on-board computers (OBC).

Tachograph is an instrument designed to indicate driver time, speed and distance and to record movement of the vehicle, speed travelled, distance covered and operation of the vehicle. The information is recorded on a special chart against a time scale by means of several styluses. Generally, the instrument is driven by a flexible driver shaft from the transmission gearbox connected through an adaptor gearbox. Recent developments in tachograph technology have led to the introduction of electronic drive. The advantage of this new technologies the elimination of defect-prone corrector gearboxes and cable drive systems.

Taximeters, originally developed to calculate taxi fares, have been advanced using new technology to measure and record many vehicle/driver/passenger characteristics. The latest taximeters are now capable of monitoring distance and time (by passenger, in the shared-ride meters), speed, fuel consumption, engine RPM and other operating variables. The information is recorded in memory and can be retrieved via digital read-outs on the display unit.

Computer-based vehicle management systems represent a higher level of technology. A wide range of vehicle management systems are currently available, varying in levels of sophistication and cost. Typical vehicle parameters monitored by the systems include RPM, speed (km/h or mph), trip distance (km or mi), ignition on/off, water temperature and oil pressure. Information is fed continuously from sensors to the computer. Some systems make provision for entering manually additional information such as fuel purchased or other expenses.

Onboard computers (OBC) for individual vehicles include some of the technology, such as vehicle sensors, utilized in fleet management systems. However, they also include vehicle control systems which may not be included for fleet management purposes. Already today, the average road vehicle has about six microprocessors. It has become apparent that microprocessors allow the transfer of a great amount and variety of information to and from vehicle operators. The OBC can provide digital readouts of instantaneous and average trip fuel consumption and journey speeds, as well as giving audible warnings of excessive speeding.

1.3.6 Image Processing Systems

Image processing systems (IPS) are systems which will both record and analyze traffic scenes automatically. Automatic license plate readers are available which use automatic character recognition (ACR) techniques to extract license plate numbers from an image of a vehicle. These license numbers can be stored or compared with a database of relevant numbers.

The technologies briefly outlined in this introduction are described in further detail in "Chapter 2: State-of-the-Art Review". "Chapter 4: Market Perspective" identifies manufacturers and suppliers in the relevant fields of technology. "Chapter 5: International Programs" describes international research, development or demonstration programs utilizing the various technological approaches.

1.4 Vehicle Dynamics

1.4.1 Obeying the Laws of Physics

Most drivers have little understanding of the vehicular dynamics taking place as they drive. Professional stunt drivers probably are most knowledgeable of these factors and sometimes work with engineers using computers to plan a new vehicular stunt. The majority of drivers on the highways have a feeling for how much room they need to stop on a dry road surface and how fast they can speed around a familiar roadway curve under normal conditions; but they are easily fooled by abnormal situations. Most single-car accidents by non-impaired drivers are caused by loss-of-control due to this type of limited ability.

It is not reasonable to train every driver in the complexities of vehicle dynamics. There is a definite need for additional systems to assist the driver in these situations. Sophisticated computers and sensors will be required to perform an analysis of real-time vehicle dynamics and to intervene with warnings or overt action when the driver is exceeding safe limits for the existing operating conditions. It is interesting to note that new systems such as anti-lock braking and active suspensions will, themselves, alter the familiar driver-perceived cues and in some cases may lead the driver into a sense of false security that might result in an accident.

The vehicle motion has six degrees of freedom. These are longitudinal, lateral, vertical (or bounce), roll, pitch and yaw. Pitch, roll and yaw are rotational motions about the vehicle's centre-of-mass. The longitudinal, lateral and vertical motions are translational displacements of the centre-of-mass. Driving forward is a positive displacement of the vehicle's centre-of-mass along the longitudinal axis. Backing up would be a negative displacement or translation. Turning requires a yaw rotation about the vertical axis. Dips and hills cause pitch rotation about the lateral axis lifting or lowering the nose of the car.[2]

The contact force between the tires and the road surface is a controlling factor which places finite limits on the controlled behaviour of the vehicle. The size of the tire/road contact-patch varies with vehicle wheel loading, tire pressure and suspension dynamics. The tires contact the road at some distance away from the vehicle's centre-of-mass and that distance acts like a lever arm on the centre-of-mass. The suspension system adds its own set of dynamics into this coupling action. A well designed suspension system is very important to vehicle driveability.

A hopping wheel creates dramatic variations in the tire/road contact-patch and can lead to an unstable condition.

The shape of the road surface introduces dramatic variations into the vehicle dynamics. A sudden dip or pot-hole can perturb a marginally stable situation into an out-of-control situation. The shape of the road surface and its coefficient of friction are external influences that are difficult for the driver to evaluate.

Wind gusts or aerodynamic factors are also difficult disturbances for the driver to evaluate. Aerodynamic lift at high speeds can significantly reduce the tire-to-road contact force. Car makers brag about low coefficients-of-drag in the forward longitudinal direction but they say little or nothing about the sensitivity to side winds. Some vehicles are particularly sensitive to these cross-winds. Sudden lateral wind gusts can cause loss of directional control when towing camping trailers.

The longitudinal forces on the vehicle are normally referred to as traction and braking forces and are limited by the available tire-road contact force. Loss of control occurs when the tire-road contact force is insufficient and this is a non-linear occurrence that occurs suddenly when the limit is exceeded. An anti-lock braking system can assist the driver in obtaining optimum deceleration by preventing wheel lock-up. A traction control (anti-slip) system can optimize acceleration on a slippery surface. Yaw and lateral directional control during braking or acceleration is essential, undesired yaw and lateral motion occurs when the vehicle skids. The steering system is the main

---

2) Vehicle dynamics terminology is defined in SAE J670e

control over yaw and lateral motion, but other disturbances can be coupled to these axes as well. The major advantage of anti-lock brake systems and traction control systems is that steering or directional control can be maintained during a panic stop or during rapid acceleration.

Some interesting mathematical models of the dynamics of vehicles are presented in Reference 2.

1.4.2 Sample Resolutions

An active suspension control system can significantly reduce vehicle body roll, pitch and heave. Body roll is one of the cues used by today's drivers to warn them of impending loss of cornering control; so here, again, there is need for some new cue or warning to the driver to protect him/her from exceeding the physical limits determined by the laws of physics.

By limiting body roll, the active suspension system will allow the tire-to-road contact force to be maintained under a higher cornering force. The vehicle can therefore be driven around curves faster than a vehicle without active suspension control. This allows the average driver to push the vehicle closer to its natural limits of performance; unfortunately this might result in a more severe accident if loss of control does occur due to excessive cornering force. It should be apparent therefore that future automotive systems need to offer new driver cues, warnings or intervention to provide for safe operation.

Steering, braking, suspension and engine actions are interactive with each other. Braking tends to pitch the vehicle nose down. Rapid acceleration tends to make the vehicle squat rear down. Cornering tends to roll the vehicle and braking during cornering tends to cause an undesired steering action. Because these systems interact through the laws of physics, it makes sense to look for an integrated chassis control system wherein the expected interactions are taken into account during the computer control calculations.

Toyota's FXV-II concept car incorporated an experimental integrated chassis control system which showed that the average driver, so aided, could achieve performance in excess of a skilled driver in a conventional vehicle without the control system. Much more engineering development is required in this area and more attention to driver cues (information feedback to the driver) is required.

1.5 Travel Support Systems

Comprehensive travel support systems will ultimately incorporate a full range of traffic information broadcasting functions, interactive trip planning functions and entertainment/communication functions. While the technologies for broadcasting systems based on highway advisory radio (HAR), and automatic highway advisory radio (AHAR), have been available for a long time, these capabilities have not been exploited in either Canada or the United States.

With the recent emergence of the radio data systems (RDS), and based on the established record with various teletex on-line systems, it is expected that travel support systems will advance quickly in the future. As they will provide significant "value added" to the autonomous vehicle navigation systems, their large-scale introduction will have a major impact on the market penetration of these devices.

2 STATE-OF-THE-ART REVIEW

2.1 Automatic Fleet Monitoring Systems

2.1.1 Automatic Vehicle Identification

Automatic vehicle identification (AVI) is the term used for techniques which uniquely identify vehicles as they pass specific points on the highway, without requiring any action by the driver or an observer. AVI systems [3] essentially comprise three functional elements (basic system diagrams are presented in Exhibit 1):
- vehicle-mounted transponder or tag
- roadside reader unit, with its associated antennas
- computer system for the processing and storage of data.

At the simplest level, information which identifies the vehicle is encoded onto the transponder. This normally consists of a unique identification number, but can also include other coded data. As the vehicle passes the reader site, the transponder is triggered to send the coded data via a receiving antenna to the roadside reader unit. Here, the data are checked for integrity before being transmitted to the computer system for processing and storage.

Two-way communication is also possible with some AVI systems. Here, data flow occurs in both directions, with coded messages being transmitted between the reader unit to vehicle-mounted transponders. More sophisticated technology is needed for this type of system, with additional capabilities required in both the roadside and vehicle-based equipment.

Several approaches to automatic vehicle identification have been developed since the first investigations of AVI were carried out in the l960s. Recent advances in vehicle detection and data processing techniques have made the application of AVI systems both technically and economically feasible.
AVI systems can be divided into four main categories:
- optical and infrared systems
- inductive loop systems
- radio frequency and microwave systems
- surface acoustic wave (SAW) systems.

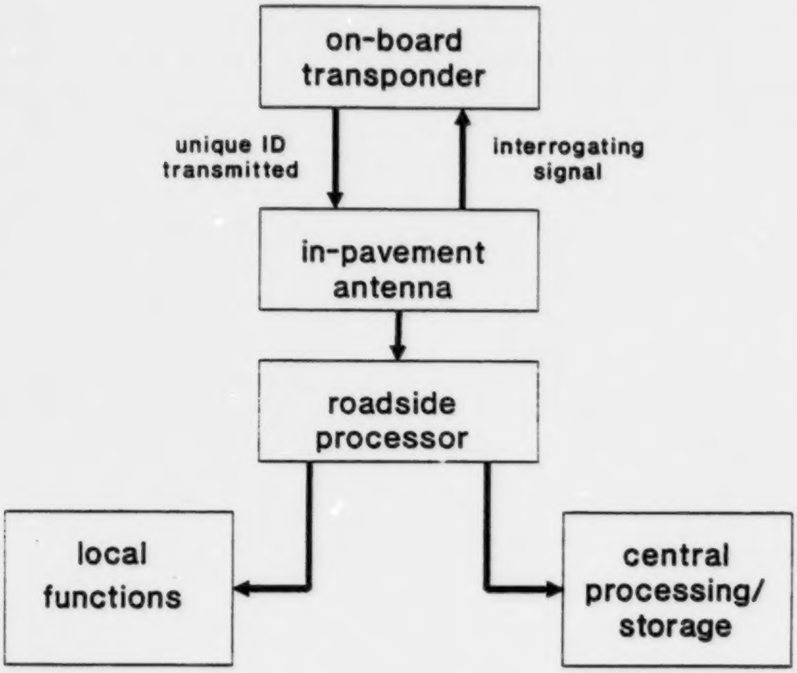
a) Optical and Infrared Systems

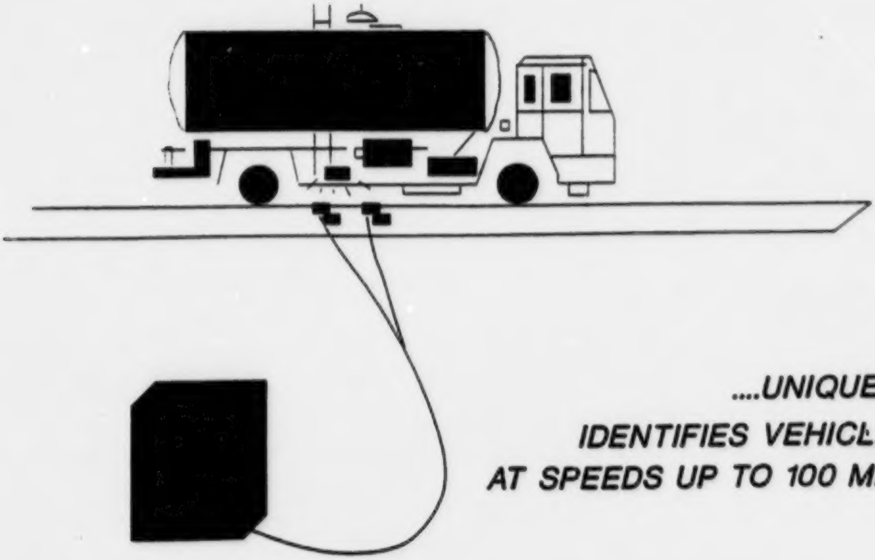
Optical systems formed the basis of the earliest AVI technologies developed in the l960s in the U.S. and Europe. However, optical systems require clear visibility, performance being seriously degraded by snow, rain, ice, fog or dirt. They are also

EXHIBIT 1

AUTOMATIC VEHICLE IDENTIFICATION

System Diagrams


on-board transponder
unique ID transmitted
interrogating signal
in-pavement antenna
roadside processor
local functions
central processing/ storage



....UNIQUELY
IDENTIFIES VEHICLES
AT SPEEDS UP TO 100 MPH

sensitive to reader/tag misalignment, focusing problems and depth-of-field limitations, though improvements in performance have been achieved in recent years. A recent project undertaken at the University of Arkansas carried out investigations into bar-code optical AVI systems. The results suggest that, even with modern technology, the level of reliability of optical AVI is too low for most highway transportation applications.

Infrared systems were tried during the l970s as a substitute for the earlier optical approaches, but were found to share many of the problems of the earlier optical systems, being similarly sensitive to environmental conditions. AVI applications usually require very high read reliability levels and the fundamental nature of these problems is such that both optical and infrared approaches have been largely abandoned by AVI manufacturers.

b) Inductive Loop Systems

Inductive loop AVI systems use conventional traffic detection and counting loops in the highway pavement to detect signals from transponders mounted on the underside of vehicles. These approaches can be divided into active, semi-active and passive systems, according to the source of power used by the vehicle-mounted transponder.

Active systems use a transponder which takes its power supply from the vehicle on which it is mounted. These systems may transmit an identification code continuously, or, more often, they are triggered by a signal from the inductive loop in the pavement. As the power supply for transmission of the vehicle ID code is not significantly limited, they can theoretically be picked up over wide range of lateral positions on the highway, given an appropriate design of inductive loop array.

Passive systems use a transponder which is energized by power transmitted from the inductive loop in the pavement. Passive transponders are sealed units with no external power supply. When outside the field of the powering inductive loop, these tags are totally inactive. Passive systems are generally less vulnerable than active units to outside interference and damage, whether accidental or deliberate.

Semi-active systems have been developed most recently and use an internal battery to provide power to transmit the vehicle ID code when triggered by an inductive loop. These totally sealed units require no external power supply, and therefore overcome the problems of the fully active system. Although semi-active inductive loop vehicle ID systems are relatively unproven, they seem to offer a particular balance of advantages which could make them most appropriate for any AVI system design scenarios.

c) Radio Frequency and Microwave Systems

Radio frequency (RF) and microwave systems have generally adopted roadside or railroad trackside antenna layouts, transmitting and/or receiving on a wide range of frequencies in the kHz, MHz and GHz ranges. However, systems utilizing in-pavement microwave antennas are now being developed which eliminate problems of occlusion of the line-of-sight between the transponder and antennas. Like inductive loop systems, RF and microwave technologies can be divided into active, semi-active and passive approaches.

Typically, in a passive microwave application, an encapsulated transponder is attached to the side of a vehicle or container. The transponder contains a small internal receiving antenna, an internal transmitter and solid-state electronic circuitry. The roadside reader unit illuminates the transponder with a fixed RF frequency, some of which the transponder absorbs, converts and transmits back to the reader unit, in a form containing the ID code. Conversion may be to an harmonic frequency or simply by polarization and modulation of the radiated signal.

One advantage of microwave systems is that they can transmit data at much higher rates than inductive loop systems, as they operate at higher frequencies. Consequently, this increases the amount of data that the system can handle. Microwave transponders tend also to be smaller in size than inductive loop transponders. However, a potentially serious problem associated with microwave passive systems concerns the power levels which must be transmitted in order to energize the vehicle-mounted tags. In many countries, these may violate limitations on accepted safe operating levels for microwave systems. Semi-active systems again offer a satisfactory compromise, using a sealed unit transponder with an internal lithium battery. These allow radiated power levels to be greatly reduced, while providing for a transponder design life of ten years or more.

d) Surface Acoustic Wave Systems

Surface acoustic wave (SAW) technology is the basis of a recently developed AVI system [4 and 5]. The SAW system consists of vehicle tags; a microwave reader; and a signal processor unit that interprets the tag signature and composes messages for transmission to a host computer.

A SAW tag consists of two elements, an antenna and a lithium niobate SAW chip that serves as a multi-tapped electronic delay line. The SAW chip receives an interrogating signal through the attached antenna, stores it long enough to allow other reflected environmental interference to die out and then returns a unique phase-encoded signal. The key operating characteristic of the SAW chip is the ability to covert the electromagnetic wave into a surface acoustic wave. SAW tags overcome concerns over high microwave power levels, but are limited to purely fixed-code applications.

AVI systems currently on the market, their manufacturers and basic characteristics, are presented in Exhibit 7. (Exhibits 7 to 10 are together at the end of Section 2.1)

2.1.2 Weigh-in-Motion

Several systems for weighing vehicles in motion are currently obtainable from manufacturers in North American and Europe. The main alternatives for permanent weigh-in-motion equipment considered in this section are: bending plate systems, capacitive systems, shallow weighscales, deep pit weighscales, bridge systems, and piezo-electric systems (for system diagrams, see Exhibit 2).

a) Bending Plate Systems

Bending plate systems were developed and patented in West Germany by the Bundesanstalt fuer Strassenweisen (BAST), the Federal Road Research Institute. The BAST Weighplate, now manufactured and distributed by the PAT Corporation, uses a high-strength steel plate only 16 mm (0.625") thick, which can be used for high speed dynamic weighing when recessed into a shallow pit. Each weighplate measures 122 cm < 50 cm (4.00' x 1.66') long, two or three being used across a traffic lane, normally covering both wheel tracks. A lightweight frame supports the plates in a pit of only 5 cm (2") depth.

b) Capacitive Systems

Capacitive WIM systems are now produced by Electromatic, Golden River and Streeter Amet. All three use the same surface-mounted portable capacitive sensor. The Golden River system utilizes a portable roadside microprocessor traffic counter/ classifier. The roadside unit scans a portable weighmat every millisecond, producing a digital capacitance reading which is smoothed and processed by special algorithms. Axle counts in twelve user-defined weight bands are stored in solid state memory by preset intervals of between one minute and 24 hours on the internal clock and calender. Individual axle weights can also be displayed in any appropriate units, for checking and calibration.

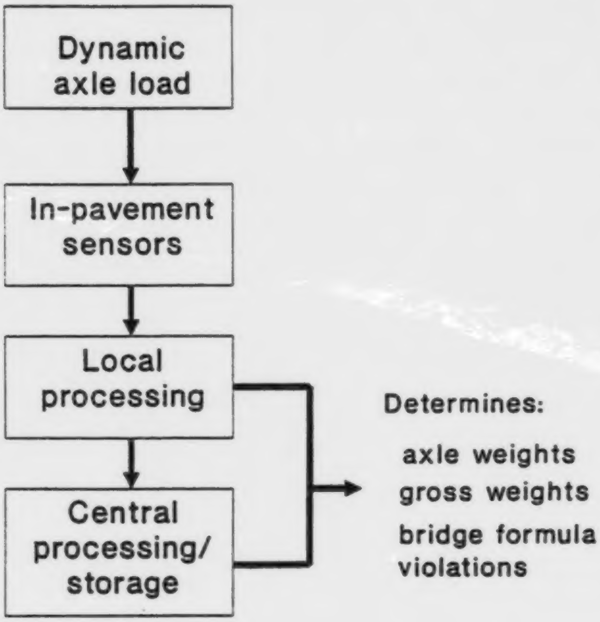
c) Shallow Weighscales

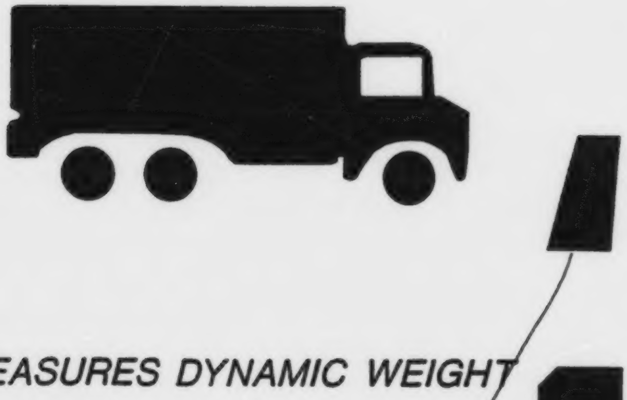
The Radian WIM system is a shallow weighscale, though very much more complex in design than the bending plate. It has been quite widely used within North America,

EXHIBIT 2

WEIGH-IN-MOTION

System Diagrams


Dynamic axle load
In-pavement sensors
Local processing
Central processing/ storage
Determines:
axle weights
gross weights
bridge formula violations



...MEASURES DYNAMIC WEIGHT

and is capable of giving good results when carefully maintained. The depth of the Radian system is less than four inches. The roadside equipment is normally located in a mobile motor home, as the system is not usually operated unattended. Some savings could be made by the adoption of microprocessor technology in signal processing, but the scale itself would remain complex and relatively expensive.

d) Deep-pit Weighscales

The University of Saskatchewan/IRD automatic highway scale is a deep-pit system, with two rectangular weighing platforms resting on a common concrete foundation. One platform is located in each wheel track. Loads applied to a platform produce a vertical movement in a centrally located oil-filled piston, which acts as a load cell. Inductive loops and a roadside monitoring system allow a range of vehicle parameters to be measured.

e) Bridge Weighing System

The bridge weighing system was first developed in the U.S. at Case Western Reserve University. In its current form, reusable strain transducers are clamped to the support beams of a highway underbridge. Tape switches are placed on the road surface for the measurement of vehicle speeds. An optional manual input is also possible for detailed vehicle classification via a portable control box. Data recording is performed via a minicomputer system and dedicated electronic apparatus mounted in a mobile instrumentation van parked near the bridge. Individual truck speeds, axle weights and gross vehicle weights are displayed on a TV monitor or printed in real time. These data are also stored on a microcomputer floppy disk.

f) Piezo-Electric Axle Load Sensors

Piezo-electric axle load sensors, made from a copper-sheathed coaxial cable, have been utilized in France, West Germany and Britain for some years and have been the subject of extensive research efforts in several European countries. These sensors offer the potential for a low cost, permanent axle weighing system. Weigh-in-motion systems based on piezo-electric sensors have undergone extensive testing in Britain, the U.S. and Canada. Another type of piezo-electric axle load sensor consists of a thin plastic film known as PVDF.

WIM systems currently on the market, their manufacturers and basic characteristics, are presented in Exhibits 8a-8d.

2.1.3 Automatic Vehicle Classification

General requirements for automatic vehicle classification (AVC) systems and sensors are that they should be low cost, easy to install, and above all, reliable. Several technologies are available which meet these requirements in specific applications (for system diagrams, see Exhibit 3). The use of solid-state electronic components, with microprocessor control and CMOS memory data storage, has reduced design and reliability problems.

The installation of the classification equipment requires the sensors to be fixed, either permanently or temporarily to the road and connected to the roadside unit, containing the detector, processor and recording device. The data collected can be held in the roadside unit for eventual retrieval, or stored temporarily prior to transmission to another unit for further processing and display.

There are three approaches to sensor design which can provide data for automatic vehicle classification: presence sensors (usually inductive loops); axle sensors; or combinations of presence and axle sensors.

a) Presence Sensors

Inductive loops are easily installed in the road or on the road surface. For permanent applications, they are placed in diamond saw-cut slots, back-filled with epoxy resin or bituminous compounds. Temporary sites commonly utilize loops that are taped to the highway surface. When inductive loops alone are used for automatic vehicle classification, two loops are placed at a fixed distance apart. Using this configuration, time of passage between the loops and the average duration of presence over them can be obtained. Magnetic signature and chassis height can also be obtained from the loops. Vehicle classification is determined by one or more of these parameters.

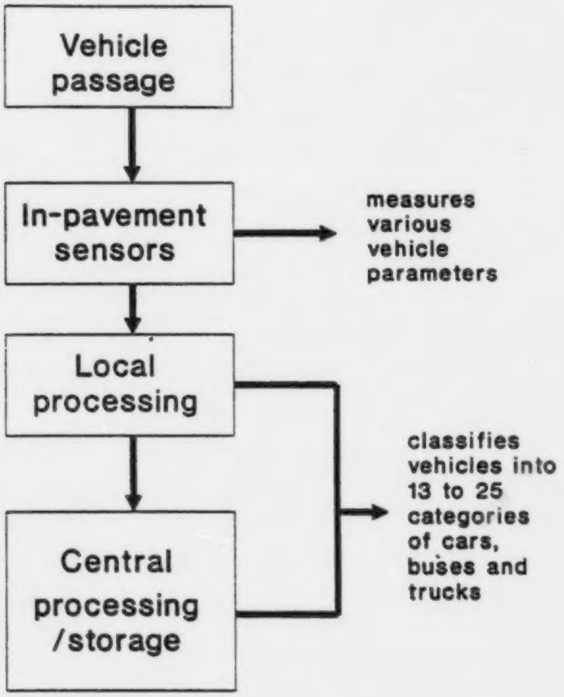
Inductive loop technology is flexible, since the loop configuration or design can be adjusted to suit particular counting and classification applications. Loops cannot be used to count axles reliably, because the loop is activated by the entire chassis of the vehicle. However, for presence sensing they have the merits of being low cost, reliable and widely used.

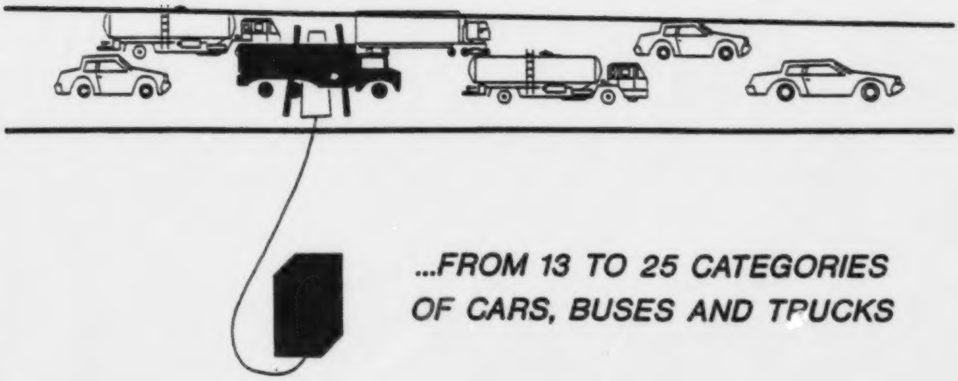
Optical and infrared sensors may take many forms ranging from simple light beams, broken by the vehicle passage, to complex data acquisition systems using cameras to record vehicle manoeuvres. However, these sensors suffer from reliability problems, being susceptible to poor weather conditions, and offer little or no discrimination by lane. These sensors are generally not used as part of a main-line AVC system. They do, however, have applications in specialized situations including checking - parameters such as vehicle height.

EXHIBIT 3

AUTOMATIC VEHICLE CLASSIFICATION

System Diagrams


Vehicle passage
In-pavement sensors
measures various vehicle parameters
Local processing
Central processing /storage
classifies vehicles into 13 to 25 categories of cars, buses and trucks



...FROM 13 TO 25 CATEGORIES OF CARS, BUSES AND TRUCKS

Magnetic sensors operate by detecting the residual magnetic field induced in vehicles by their passage through the earth's magnetic field. These sensors have not gained wide acceptance, although they may prove to have advantages over inductive loops for certain applications. Their costs are generally higher. The development of this technology is at a relatively early stage.

Microwave and sonic sensors operate on the doppler principle by directing a beam of energy at the road and sensing the energy reflected back by moving objects. The problems associated with their use include the inability of microwave detectors to sense stationary vehicles, and the shadowing of smaller vehicles by the presence of a large vehicle in the zone of detection. Their costs are again higher than those of inductive loops, which they are unlikely to replace other than in specialized applications.

b) Axle sensors

Air hoses or **pneumatic tubes** are commonplace in portable traffic monitoring systems. The sensor is, however, susceptible to damage and has only a relatively short life.

Contact sensors use the mass of the axle to close metallic contacts in the roadway. The most common form, known as the tapeswitch, is a reusable strip fixed to the road surface. Permanent contact closure sensors are also commercially available, but their durability for long-term applications is uncertain.

Weigh-in-motion sensors are generally capable of acting as permanent axle sensors, though currently at a high cost.

Capacitive sensors use axle mass to deflect one of two parallel plates, thereby changing their capacitance. In a simple form the sensor may be a length of coaxial cable whose inner and outer conductors form the capacitor plates. This system is closely related to the triboelectric sensor described below, which uses different signal processing electronics to achieve a similar effect.

Piezo-electric sensors generate a charge when subjected to an external stress. Two versions of this sensor are currently under development; these are piezo electric cable and PVDF piezo film. With suitable charge amplification and signal processing, they can be used successfully as an axle detector, and they may also be adapted for weigh-in-motion by means of charge amplification followed by fast analog-digital conversion of signals.

Tribo-electric sensors utilize the effect of spontaneous generation of charge with friction between certain materials. These sensors are composed of coaxial cable which exhibits the tribo effect when vibrated or flexed. They may be stretched across the roadway without any mounting for short-term applications. Alternatively, they can be mounted in flexible polyurethane to form a more permanent and robust sensor fixed into a slot in the road surface.

c) Combinations of Presence and Axle Sensors

This third approach to AVC sensor design uses a combination of either one presence detector (inductive loop) and two axle detectors, or two loops and one axle detector to determine classification parameters. By utilizing both techniques it is possible to obtain much more information about vehicles than from one technology alone. Vehicle classification can then be based on the measurement of vehicle length, number of axles, wheelbase length(s) and chassis height. The axle detectors will measure vehicle speed and wheelbase length, while the inductive loop determines vehicle length and approximate chassis height. Additionally, using this type of system, vehicle speeds and time headways can also be measured.

Once vehicle data have been obtained the classification can be determined by using a standard microprocessor to compare length, wheelbase and chassis height data, with a look-up table stored in memory. The advantage of utilizing a microprocessor is the flexibility which it provides. The presentation of the output can be varied and the classification categories altered to suit the users requirement.

2.1.4 Automatic Vehicle Location

Automatic vehicle location systems can be divided into two broad categories: ground-based systems (autonomous/non-autonomous) and satellite-based systems (for a system diagram, see Exhibit 4).

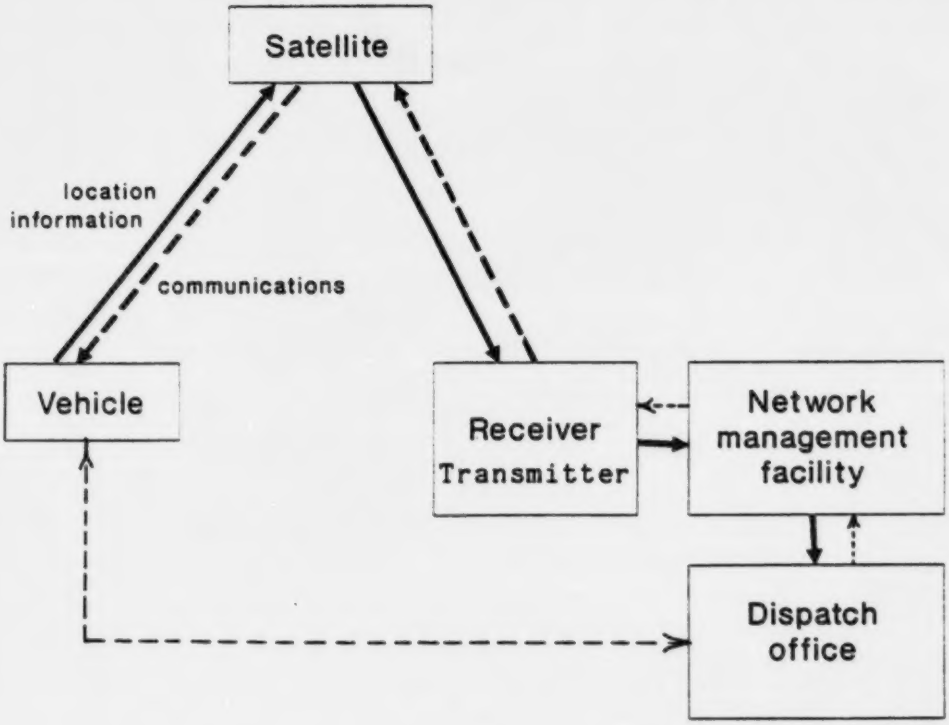
a) Dead Reckoning Systems

Dead reckoning systems are used to track a truck through knowledge of initial position, elapsed time, and continuous monitoring of speed and direction. On-board components of this approach include a clock, a magnetic or electronic compass and an odometer. Optionally the truck location may be instantaneously shown superimposed on a map via an in-vehicle display, stored in an on-board computer for subsequent access, and/or transmitted along with truck identification to a central location via a modem and two-way radio. Tracking must be continuous in order to maintain location data. Additionally, truck speed may be remotely monitored for vehicle management or enforcement purposes. Communications, however, need not be continuous to use dead reckoning AVL. Location accuracy depends on the accuracy of the clock, and the speed and direction sensors.

EXHIBIT 4

AUTOMATIC VEHICLE LOCATION

System Diagram


Satellite
location information
communications
Vehicle
Receiver Transmitter
Network management facility
Dispatch office

Dead reckoning systems use on-board equipment to maintain vehicle location without reliance on external signals. However, the passing of location information in real time to a central monitoring location is limited by two-way radio range. Therefore, dead reckoning is most appropriate for urban or short-haul applications.

b) Map-Matching Augmentation

Since vehicles are essentially constrained to a finite network of streets and roads, it is possible to match a vehicle's dead-reckoned course with a mathematically mapped route.

Graph theory is used as the conceptual framework for mathematically modelling maps of roads and streets as internodal vectors. Each vector represents the distance and direction of the road between two nodes defined by their coordinates. Therefore, a particular route from a given initial location is a unique combination of vectors defined by the sequence of nodes along the route.

The pattern of the vehicle's path is analyzed as a sequence of vectors that may be deduced from any of a variety of dead-reckoning processes. As the vehicle travels, its measured vector sequence is continuously compared with the mapped vector sequence. Each time a turn is executed whose sense, magnitude, and location approximate those of a nearby mapped turn, the vehicle is presumed to be at the mapped location. The matching process thus removes any dead-reckoning error accumulated since the last turn.

However, problems can still arise from any deviation from the coded vector system. Movement in a multi-level, multi-exit garage or very closely-spaced intersections can affect a dead-reckoning compass. In these cases, a manual correction to reposition the system onto the correct vector of the map data base may have to be performed.

The Automatic Route Control System (ARCS), demonstrated by French and Lang [6], was the first such map-matching route system. ARCS allowed a particular route to be "programmed" as a unique sequence of mathematical vectors. An on-board computer was used to analyze dead-reckoning inputs and match the deduced vehicle path with programmed routes to automatically remove position discrepancies that would otherwise accumulate.

ARCS used a differential odometer for dead reckoning and a map-matching algorithm to correlate each sequentially measured route vector with its map data base counterpart. The vehicle's location along the route was confirmed, and prerecorded audio route guidance instructions were issued where appropriate. A second version issued visual route instructions on a plasma display panel. This subsequent version, known as "Routeware," [7] yielded an average location accuracy of 1.15 metres during extensive testing.

c) Proximity Beacon Systems

Proximity beacon systems use strategically located short-range transmitters to send location-coded signals indicating the instantaneous location of a receiving vehicle. An on-board system receives and stores a location code as the vehicle passes a proximity beacon or "electronic signpost." The on-board equipment is periodically polled using two-way radio. The location of the latest proximity beacon and the distance travelled or time since passing the beacon are automatically radioed to a central computer. Such systems have been used by Canadian transit properties, including Toronto and Hamilton, for some years.

Several variations of the proximity beacon approach, some involving two-way communications with suitably equipped vehicles, have been investigated for interactive route guidance. Typically, the driver enters a destination code on an in-vehicle panel. This is automatically transmitted to a roadside unit as the vehicle approaches instrumented intersections. The roadside unit, which may operate autonomously, or be part of a networked system, analyzes the destination code and instantly transmits route instructions to the vehicle. Alternatively, the roadside unit may transmit its location to the vehicle where an on-board computer utilizes stored road network data to generate instructions for continuing the route from the identified location.

d) Cellular Telephone/Radio Communications Systems

Cellular telephone/radio communications systems have provided a major step forward for both business and personal voice communications in the automotive environment. The potential for cellular telephone data communication is expected to broaden cellular applications in the coming years. However, at present the use of cellular technology exclusively for full-duplex individually addressed communications will limit potential uses in conjunction with vehicle location systems.

For providing positioning capability, these systems will also have to significantly improve their position accuracy; if this is not possible through careful "electronic mapping" of each urban area's air space (along the street networks), then an extensive and expensive grid of proximity devices will be required to provide localized position correction. The costs would of course be reduced if a beacon system already exists for monitoring the positions of transit vehicles and/or if transponders are installed network-wide for traffic monitoring and enforcement purposes.

Effective adaptation of cellular radio technology to the data communications requirements of vehicle location is likely to require a dedicated channel for repeated broadcasting of the same map update data and traffic data by all cell transmitters in a local area. Equipped vehicles would require a special receive-only unit to detect the data for transfer to the on-board system.

e) Radio Determination Systems

Radio determination is the term applied to electromagnetic position fixing using modulated and coded radio-frequency radiation. Radio-frequency transmissions from a vehicle are detected at three or more fixed points and the vehicle's location is determined by triangulation.

Most ground based radio determination systems are local in range. However, the North American continental Loran-C and the world-wide Omega system provide wide area coverage. At present Loran-C beacons are concentrated near the coasts. However, the U.S. Federal Aviation Administration and the U.S. Coast Guard are scheduled to begin extending Loran coverage into the mid-continent area. Three commercial companies are currently offering Loran-based vehicle location systems: Telesat Mobile Inc's ROADKIT system; Motorola, with its Automatic Vehicle Location System; and II-Morrow, with its Vehicle Tracking System.

f) Satellite-based AVL Systems

Satellite-based AVL systems operate by precise timing of signals transmitted from a ground station, through two or three satellites, to a receiver. By looking at the difference in the time of arrival of signals routed by each satellite, the distance of the receiver from each satellite can be calculated. This leads to a position fix in three dimensions through trilateration.

The **TRANSIT** satellite navigation system [8 and 9], implemented by the U.S. Navy, has been operational since 1964. Several TRANSIT satellites in polar orbits at a height of approximately 1075 km are longitudinally-spaced to give worldwide, albeit intermittent, coverage. Each satellite transmits information which, in combination with measured Doppler characteristics, permits calculation of receiver location by iterative solution of a set of equations. Since a TRANSIT satellite is not always in range, vehicle systems based on TRANSIT must include dead reckoning for continuous determination of position between satellite passes.

The **NAVSTAR/GPS** is a U.S. military planned system also available for civilian use [10]. A full constellation of 21 orbiting satellites and three active spares will provide continuous global navigation fixes (present constellation: previously 6 Block I satellites in place, 1989 5 Block IIs launched, 1990 6 Block IIs planned). This system will also support location, velocity, and time determination. Both military and commercial levels of position accuracy will be provided. Civilian/commercial accuracy is between 11 m and 24 m using an on-board computer.

GPS is a one-way system in which users establish their own locations without provision for reporting to other users. GPS receivers perform complex timing and computation functions relative to the orbiting satellites and are therefore generally expensive. At the proposed time of implementation of NAVSTAR/GPS, manufacturers suggest that receivers will be about the size of a car radio. Once the position of a vehicle has been found, it is still necessary to transmit its location to a central point for determining vehicle location which would add further cost.

In contrast to the GPS approach, the **Radio Determination Satellite Services** (RDSS) system [11 and 12], proposed by Geostar Corporation, uses fixed location geosynchronous satellites and centrally based system intelligence.

- ground station + large computer shared by all RDSS users to perform all data processing for positioning, satellite up- and down-link vehicular data communication, and communication links to customer processing sites

- geosynchronous satellites – three for U.S. coverage, eight for global coverage as required

- user transceivers identified through a built-in code.

In operation, RDSS positioning is initiated by the ground station which sends an interrogation signal via satellite. These interrogation signals are encoded to select specific vehicles for position determination. The signal is received by the transceiver onboard the truck, which responds by sending a time marked signal carrying the unique vehicle identification code. This is then relayed via a minimum of two satellites back to the ground station. The ground station computer compares the signal travel times via the two satellites and uses the fixed satellite positions to calculate the vehicle position by trilateration. The position information is transmitted back to the vehicle transceivers via communication links to the ground station. Total sequence time is less than one second. This sequence may be initiated by activating the ground station interrogation in a number of ways, either by preset time intervals, by driver request, by trucking company request, or by enforcement agency request.

The RDSS transceiver communications path may be used to send information other then responses to ground station interrogation signals. Thus, the transceiver may have a keyboard for sending messages to other RDSS users or anyone linked to the

RDSS's central computer. Geostar's U.S. location accuracy is calculated to be one to seven metres. A 1983 study indicated the Geostar system can provide of the order of 100 million transactions per hour, divided between position fixes and messages in 32 character blocks. AVL systems currently on the market, their manufacturers and basic characteristics, are presented in Exhibits 9a-9b.

2.1.5 Automatic Vehicle Monitoring

a) Introduction

Automatic vehicle monitoring (AVM) systems are a class of systems which combine AVL, WIM, AVC and AVI technologies with various in-vehicle devices. Automatic vehicle location (AVL) systems are used for providing vehicle location information to a central control, rather than to the driver. Weigh-in-motion (WIM) are used to obtain the axle and gross weights of vehicles using in pavement sensors while they are travelling along the highway. Automatic vehicle classification (AVC) systems are used to collect classified traffic data. Automatic vehicle identification (AVI) systems are used to uniquely identify vehicles as they pass specific points on the highway without requiring any action by the driver or an observer.

The in-vehicle devices range from simple tachographs through taximeters to full computer-based management systems and on-board computers. A system diagram is presented in Exhibit 5.

b) Electronic Tachographs

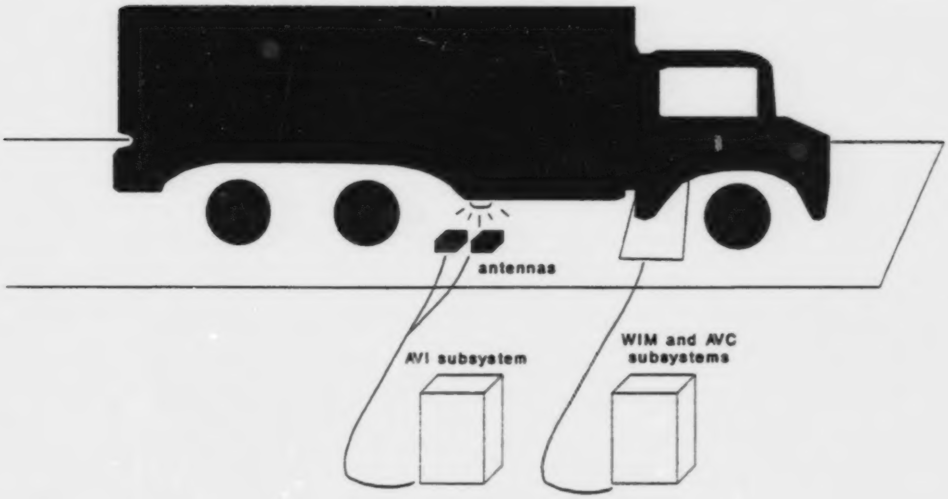
As early as 1939 a "journey recorder", the forerunner of the tachograph, was mandatory for all passenger buses in Germany. The instruments became mandatory by law in that country in 1953 for trucks over 7620 kg (16800 lbs) GWT. Nine European countries now require tachographs to be installed on vehicles over 3630 kg (8000 lbs) GWT, all vehicles involved in hazardous materials transportation and all buses with more than nine passenger seats (excluding transit buses on scheduled routes). Similar regulations apply to specific categories of vehicles in other parts of the world.

The tachograph is designed to indicate to the driver time, speed and distance and to record movement of the vehicle, speed of travel, distance covered and operation of the vehicle. The information is recorded on a special chart against a time scale by means of several styluses. One stylus is utilized for each of the functions. A fourth stylus is sometimes included as an operator option if further information is required, such as the monitoring of fuel consumption. Some tachographs record the RPM and total distance and speed.

EXHIBIT 5

AUTOMATIC VEHICLE MONITORING

System Diagram


antennas
AVI subsystem
WIM and AVC
subsystems

The operation of the different types of tachographs is similar. Prior to the start of a journey a new circular recording disc is inserted into the tachograph. Once inserted, the disc begins to rotate and, so long as the clock continues to operate, the face of the tachograph remains closed. The styluses record information on the vehicle and driver by means of engraving traces on the chart surface. Each stylus makes a distinct and clearly defined engraved trace sufficiently accurately and positioned on the chart to enable subsequent analysis to determine movement and speed of the vehicle and other driver activities to within seconds and a third of a metre. Additionally, most tachographs require the driver to make additional notes on the chart and to switch the tachograph to the activity currently being performed. The activities are driving, attendance at work (covering non-driving activities) and break and rest periods.

Generally, the instrument is driven by a flexible drive shaft from the transmission gearbox connected through an adaptor gearbox. The adaptor gearbox is intended to correct the drive ratio to ensure that speed and distance readings are within the permitted installation and use tolerances. Recent developments in tachograph technology have lead to the introduction of electronic drive. The advantage of this new technology is the elimination of defect-prone corrector gearboxes and cable drive systems. Electronic tachographs fall into two categories; those which utilize electronic pulse generators or impulse transmitters, regulators and drive motors, and those which use a microprocessor.

c) Taximeters

Taximeters, which were originally developed to calculate taxi fares, have been advanced using new technology to measure and record many vehicle/driver characteristics. The latest taximeters are now capable of monitoring distance, time, speed, fuel consumption, engine RPM, and other operating parameters. The information is recorded in memory and can be retrieved via digital read-outs on the display unit.

There are many different manufacturers of taximeters producing a wide range of devices from the basic "traditional" taximeter up to the "vehicle supervisor system" that is capable of monitoring fleet operations. Some of the systems are radio-based, with information on the status of the vehicle transmitted to base whenever the radio is set to talk mode.

d) On-board Computers

On-board computers are used to collect internal truck data and record it on a device for subsequent analysis and review. Basic OBC systems are simple, recording basic vehicle information such as tachometer, odometer, and speedometer data, power on/off signal data, oil temperature, and engine and water temperature. The collected data is stored either in a removable storage module (cassette tape, cartridge, smart card) or a recording device inside the OBC that is down-loaded at the home-base by connecting a hand-held transfer device or communication cable to the truck. A vehicle trip usually consists of a driver's daily activity, from the time of getting into the truck to the completion of the trip. Some users may record daily trip information for up to one week or longer before removing and processing that data.

On-board computers feature advantages over tachographs. OBCs provide improved vehicle management data, and allow for driver monitoring. Their operation requires no input by the user which, in turn, reduces driver paperwork. On the other hand, OBCs on their own cannot transmit data to headquarters until a trip is over, because data transfer requires a physical link to a host computer; no real-time communication is possible between dispatcher and driver, and no vehicle location data is available while the vehicle is on the road. In addition, only limited reporting capabilities are provided.

Advanced OBCs offer driver logs; for example the Canadian designed "Silent 1000" electronic trip recorder. It has an integral electronic log book, and features customer-programmable engine and vehicle overspeed and miscellaneous alarms. Recorded data is available in ASCII format for use in processing. Cadec Modular Series #3000 automatically manages the driver DOT log, and provides expense and delivery reporting. Rockwell Tripmaster Plus/Logtrack monitors driver compliance on seven- or eight-day bases; the records are audited with Tripfax V software (running on IBM XT/AT and compatibles in DOS).

2.1.6 Image Processing Systems

Image processing systems can be used to record and automatically analyze traffic scenes (for a system diagram, see Exhibit 6). Several specific development efforts are underway in both Europe and the U.S. These are briefly described.

Within the PROMETHEUS program, the U.K. Transport and Road Research Laboratory (TRRL) and Volvo are working to develop an automatic vision system for the recognition of characters in a vehicle license plate. The system is being developed to satisfy several applications:

- vehicle identification
- O-D volume measurement
- travel time measurement
- surveillance systems.

The system will comprise the following modules:
- digital image acquisition
- image enhancement and filtering
- image processing
- recognition and error detection
- data storage and operator interface.

In the United States, the 3M Company has developed a commercial automatic license plate reader (the 3M RIA-300). This system is based on earlier research and development by the Perceptic Corporation. The system is used to extract the license number from reflective U.S. license plates. The license plate is imaged by a video camera and illuminated by an infrared strobe lamp. A shuttered image of the camera's field of view is captured and analyzed to determine if a license plate exists in the image.

The 3M RIA-300 system has recently undergone field trials on the Dulles Toll Road in Virginia. The system performed well, although some shortcomings were identified. These included the inability to identify excessively dirty, partially obscured, or certain out-of-state plates.

Other image processing system developments being undertaken within the PROMETHEUS program include a video based road user detector. The system being developed by Volvo, uses a video camera with image processing capabilities to identify pedestrians, cyclists and various vehicle turning movements at intersections. The objective of the system is to optimize traffic flow at these intersections.

Finally, Saab-Scania is developing an in-vehicle image processing system for the automatic recognition of roadside traffic signs. The aim of the system development is to identify and display to the driver those signs of relevance or importance, thereby reducing the number of distractions to the driver.

Summaries of systems currently on the market, their manufacturers and basic characteristics, are presented in the following exhibits: 7 (AVI), 8a-8d (WIM), 9a-9b (AVL), 10 (IPS). There are no summary exhibits at this time for AVC or AVM.

The *Mobile Information Systems Impact Study* [1] includes a review of the state-of-the-art of in-vehicle navigation and mobile communication technologies.

EXHIBIT 6

IMAGE PROCESSING

System Diagram

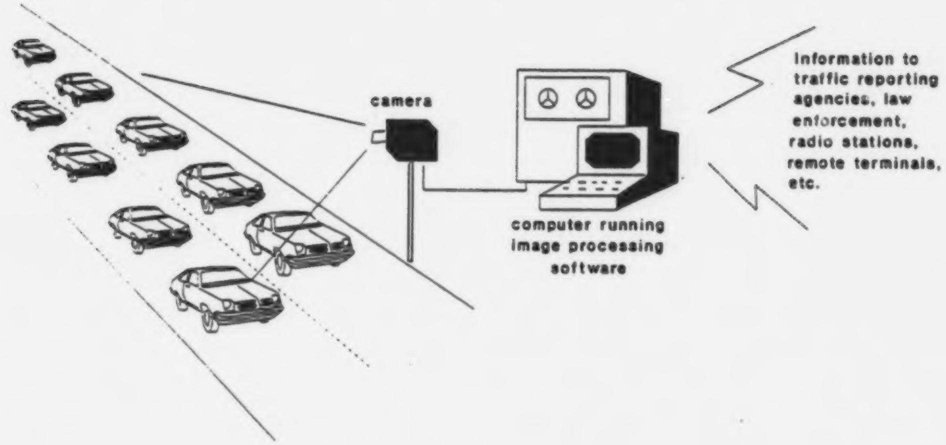

camera
computer running image processing software
Information to traffic reporting agencies, law enforcement, radio stations, remote terminals, etc.

EXHIBIT 7

AUTOMATIC VEHICLE IDENTIFICATION SYSTEMS

Manufacturer's Name	System Name	Transmission Method	System Characteristics			
			Communication		Code	
			One-Way	Two-Way	Fixed	Variable
General Railway Signal (GRS)	Identifier	Microwave/RF	*		*	
Vapor Canada Inc	ROADCHECK	Microwave/RF		*	*	*
International Road Dynamics	IRD AVI 9100	Microwave/RF(1	*	*	*	*
Corporate Strategies Inc	–	Microwave/RF	*		*	
Amtech Corporation	Electronic ID System	Microwave/RF	*		*	
Transcontrol	Setrid	Microwave/RF	*		*	
Philips	Premid	Microwave/RF	*		*	*
Identification Devices Inc	–	Microwave/RF	*		*	
Dowty Electronics	Videobus	Microwave/RF	*		*	
SAIC/ X-Cyte Inc.	ARRTS	SAW	*		*	
EMX Corporation	SVD20	Inductive	*		*	
Sarasota Automation	Visa	Inductive	*			*
Plessey Controls	–	Inductive	*		*	
Philips	Vetag	Inductive	*		*	
Philips	Vecom	Inductive		*		*

---

1) Inductive triggering alternative.

EXHIBIT 8a

PERMANENT WEIGH-IN-MOTION (WIM)

Piezo-electric Cable Systems

Manufacturer & System	Characteristics
Philips Vibracoax Piezo-electric Cable	Thermocoax (France) a unit of Philips, holds patent on piezo-electric cable and manufactures virtually all such cables originally developed in 1971
Trevor Deakin Consultants	high-speed system; tested in UK sensors mounted in rubber-filled aluminum channels
Weighwrite Weight Watcher	measures vehicles at normal highway speeds tested in UK in 1986 - technical development continuing
MAP Piezo-electric Traffic Analyzers	French systems, based on LCPC research use 2 cables mounted in slots using sand-filled epoxy resin SAFT 16 in stalled at 30 French sites both systems recently tested in the U.S.
Danish National Road Laboratory	metal section used to filter out signal noise system sensitive to road pavement, temperature tested in UK in 1986
Dutch Rijks-waterstaat	experiments with 3 mountings (epoxy bitumen block, rubber-filled U-channel, shallow rubber mat) field tested in Holland agency has stopped research into piezo sensors
International Road Dynamics Inc IRD 1060P-Piezo-electric Axle Load Classifier	developed in early 1980s; installation technique and materials minimize susceptibility to surface cracks and rut at saw cuts 5 years of installations: 7 Canadian provinces, throughout U.S., some in other countries primarily used for data collection (max standard deviation on axle weights = 10%) menu-driven software (MS-DOS, IBM-comp data collection computer)

EXHIBIT 8b

PERMANENT WEIGH-IN-MOTION (WIM)

In-pavement Pit Systems

Manufacturer & System	Characteristics
UK TRRL Dynamic Weighbridge	developed 1957; installed at 30 sites in UK measures vehicles at normal highway speeds
Trevor Deakin Cons. LOGALOAD Axle Weighbridge	measures vehicle weights in stationary and slow-speed modes (< 6 km/h)
Weighwrite ADS4	slow-speed system using a weighbeam + a load indicator in use in UK (3 sites)
Central Weighing Cons. (CWC) Series 3000	heavy-duty flush-mounted weighbridge uses 4 sealed strain gauge load cells 47 slow-speed sites, 3 high speed sites in UK
Talent Weighing Ltd Axle Weigher	slow-speed system uses 2 load cells
French Laboratoire Central des Ponts et Chausees (LCPC) Dynamic Load Balance	developed in 1967; installed at 50 French sites by 87 to to demonstrate the Thermocoax' piezo-cable uses 2 steel platforms separated by 3 quartz crystal transducers electronics (amplifiers, algorithms,..) under devt by ECM
PAT Traffic Data Analyzer DAW 200	designed for high-speed applications installed in US and several European countries including 70 sites in West Germany
International Road Dynamics CMI/IRD WIM System	originally developed at University of Saskatchewan installed in 8 Canadian provinces (25sites/42lanes), and in 12 US states (36/59) plus in Egypt (6), China (2) and UK (1) (1990 figures) selected for use in Minnesota due to favourable performance at very low temperatures (hermetically sealed)
Radian WIM-1E System	small thickness of weigh scale (50mm) can be placed in road pavement without special strengthening in use in US, Mexico and Australia
Chronos Richardson-Rollweigh/Sarasota Automation	features multiple platform static scales in use at several sites in US
Australian Road Research Board (ARRB) Low-Speed and High-Speed Electronic Mass Units	low-speed version measures vehicles at speeds < 5 km/h high-speed version measures at speeds up to 120 km/h EMUs tested by ARRB and in use in Australia (culverts,..)

EXHIBIT 8c

PORTABLE WEIGH-IN-MOTION (WIM)

Capacitive Weighmat Systems

Manufacturer & System	Characteristics
South African National Institute for Transport & Road Research Capacitive Weighmat System	initial developers of capacitive weighmat systems NITRR developed TDL system now marketed by Truvelo (see below)
Electromatic (Pty) Ltd Traffic Axle Weight Classifer (TAWC)	supplies weighmats to other WIM equipment suppliers system is widely used in South Africa tested in Britain, Holland and Jordan
Truvelo Traffic Data Logger (TDL) & Traffic Data Logger—Junior (TDL-300)	both systems use capacitive weighmats
Golden River Weighman & Marksman 600	measures vehicles at highway speeds; tested in US and UK used in conjunction with Electromatic capacitive weighmat classifier uses capacitive strip sensors
Chronos Richardson Capacitive System	used in conjunction with Electromatic capacitive weighmat being tested in US
PAT Capacitive System	used in conjunction with Electromatic capacitive weighmat prototype system was recently evaluated in US

EXHIBIT 8d

OTHER WEIGH-IN-MOTION SYSTEMS

Manufacturer & System	Characteristics
Bridge Weighing Systems Inc Fast Weigh	in use in US, Sweden, Australia uses strain transducers fitted to bridge support beams
Australian Road Research Board (ARRB) Axway	measures vehicles traveling at highway speeds features mechanical strain amplifier fitted to bridges through portable sensors
Australian Road Research Board (ARRB) Culway	measures vehicles traveling at highway speeds features strain-gauged transducers fitted to culverts, pipes, or concrete boxes that serve as weighing devices

EXHIBIT 9a

AUTOMATIC VEHICLE LOCATION SYSTEMS

Ground-based AVL Systems

System	Manufacturer	Characteristics
Tracknet AVL-200	Motorola, Inc.	LORAN-C interface
Vehicle Tracking System	II-Morrow, Inc	LORAN-C interface
METS TRACKER	METS, Inc	LORAN-C, GPS and dead-reckoning systems interfaces
AUTOTRAC	Spectrum Cellular Corporation	LORAN-C interface
Etak Navigator	Etak, Inc	on-board navigation system
GEC TRACKER	GEC (UK)	dead-reckoning systems interface
PINPOINT	British Telecom	dead-reckoning systems interface [under development]

EXHIBIT 9b

AUTOMATIC VEHICLE LOCATION SYSTEMS

Satellite-based AVL systems

Service	Authorized Providers	Characteristics
Radio Determination Satellite Services (RDSS)	Geostar Corporation, MCCA American Radiodetermination Corp, McCaw Space Technologies, Omninet Corp.	Commercially-operated, satellite-based AVL service capability to send&receive short data messages no support of voice communications
GEOSTAR AVL System	Geostar Corporation	marketing aimed at vehicle fleet monitoring and management currently in implementation stage
Road KIT (WAVM)	Telesat Mobile Inc in Canada AMSC in USA	satellite-based 2-way data message mobile communications and vehicle positioning service 2-way voice communication can be added in 1993 aimed at fleet mgt market; currently in service products manufactured by Canadian Astronautic, Gandalf Technologies, Hugh Network System

EXHIBIT 10

IMAGE PROCESSING SYSTEMS

System	Manufacturer	Characteristics
Trap Camera	Computer Recognition System Ltd	Digital picture storage no film processing needed in use in U.K.
IPL 5000	Integrated Photomatrix Ltd	Linescan camera provides a low-cost high resolution device for use in inspection and on-line process control
RIA-3000	3M Traffic Control Materials	Electronic imaging subsystem or digital image processor and special reader recognition algorithms
Model 9200	Perceptics	Integrates transform domain processing, spatial domain processing and menu driven operation
Image Processing	Dep of Civil Enginrng Univ of Minnesota	Under development
Image Processing	GTL and Porsche	Under development

2.2 Vehicular Monitoring and Control

2.2.1 Introduction

On-board vehicular monitoring and control systems are now becoming very sophisticated. Automotive instrumentation was for many years limited to the essentials of fuel quantity, coolant temperature, oil pressure, speed and distance travelled. The tachometer was an early enhancement. Safety motivations brought about additional monitoring of such items as the parking brakes being set, or a door being not latched. The locking steering column led to the key-in warning buzzer. Seat belt legislation led to the requirement for a seat belt monitoring system which was later simplified to a ten-second "fasten your seat belt" message.

Electronic control systems came into being in U.S. and Canadian production passenger cars during the mid-seventies as the result of two major factors:
- the federal legislation (U.S.) of exhaust emissions and fuel economy, and
- the concurrent evolution of the large scale integrated circuit (LSI) micro-processors.

The American automobile industry was faced with the technical and economical problems of reducing both noxious emissions and fuel consumption without major loss of driveability or performance. This led to the need for relatively complex engine operating stratagems or algorithms.

Fortunately for the automotive industry, the semi-conductor segment of the electronics industry was then introducing low cost microcircuits capable of executing complex logic sequences. These micro chips, known as **large-scale integrated circuits**, quickly evolved into computers-on-a-chip or micro-processors. With the advent of these low cost micro-computers, Japanese and European automotive manufacturers also selling in the American market began to produce electronic engine control systems and after a natural cycle of development and cost reduction began to use similar control systems on vehicles produced for their own internal markets.

While most of the initial applications of electronic vehicle monitoring and control systems were aimed at meeting the legislated requirements for the American automotive market, some producers were investigating the feature values of new systems in improving the marketability of their vehicles. In 1976, the French producer, Talbot, introduced an "Ordinateur de bord" or trip computer as an optional feature product. This vehicle monitoring system measured fuel flow, time and distance travelled to provide the driver with both real time and historical information of his driving performance and fuel economy. The product helped win a "Car of the Year" award for the vehicle manufacturer.

Since the mid-seventies, **micro-computers** have continued to be utilized in multitudes of vehicle applications, no longer limited to passenger cars. Large trucks, earth movers, mining vehicles, specialized farming vehicles and other off-road vehicles all offer a variety of specialized monitoring and control system applications. The personal passenger car, however, remains the largest marketplace for on-board electronic vehicle monitoring and control system products.

The total electronics content of American/Canadian produced passenger cars has increased from the $50 AM radio in early 1960s to some $900 today; or to well over $1000 for the up-scale models. The typical 1990 premium passenger car has a variety of micro-computer sub-systems, interconnected through data links to allow the sharing of information and the control of appropriate interactions. By year 2000 these systems will be even more extensive and in wider application, bringing the estimated electronics content to $2000 per vehicle.

2.2.2 Power Train Control Systems

a) Engine Control

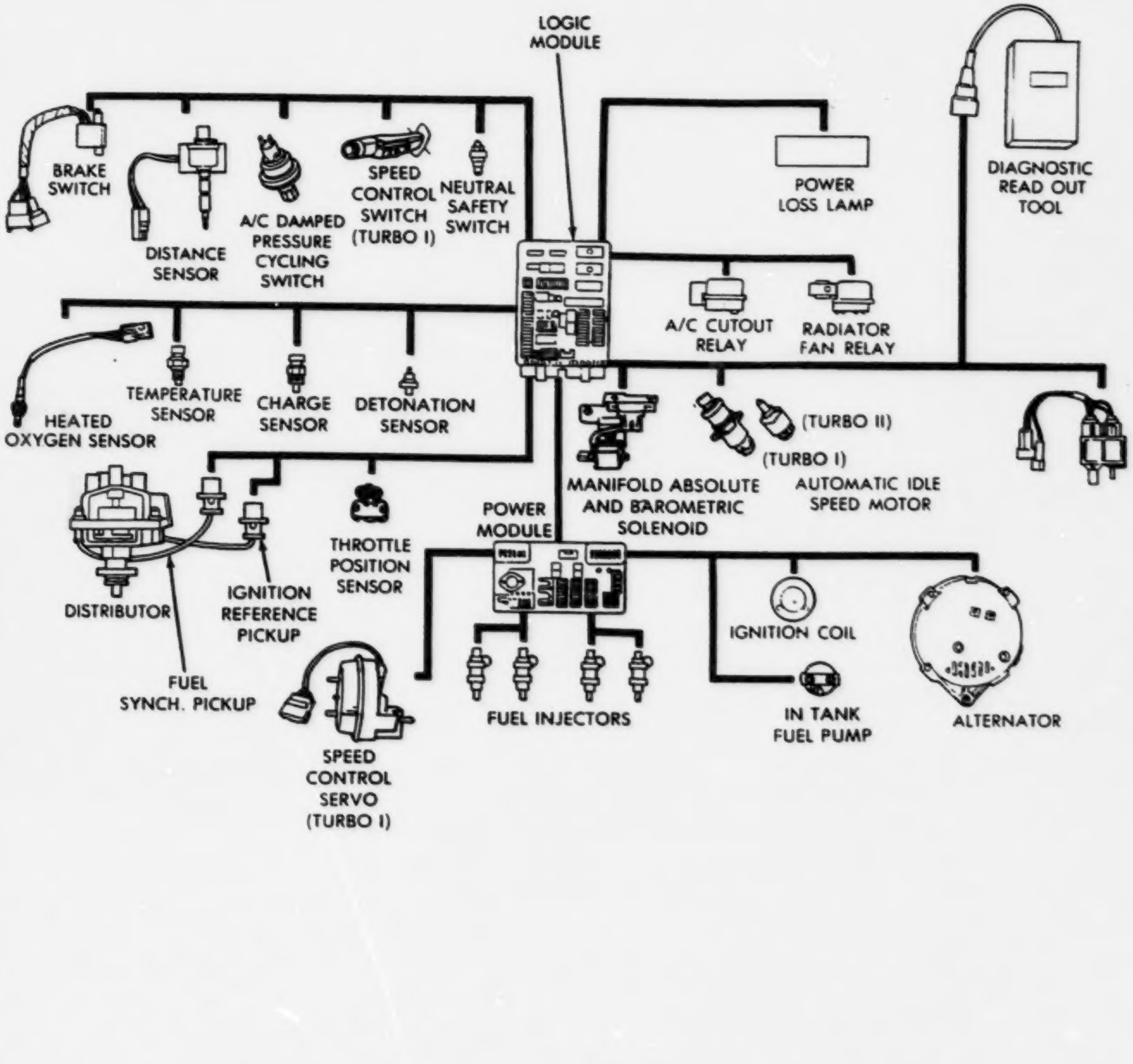
Engine control systems control the injection of fuel in accordance with the appropriate fuel/air ratio and deliver the ignition spark at the required precise angle of engine rotation. To perform this function, the engine control system monitors and or computes a number of parametric measurements such as engine revolutions per minute (RPM), fuel flow, air flow, engine coolant temperature, battery voltage, etc. Engine throttle position and intake manifold pressure are other air flow related parameters that are commonly measured. Some of these measured or derived parameters are needed by other sub-systems and are therefore made available on a data link.

Electronic fuel injection is now commonplace and may be multi-point or single-point. In multi-point systems, an injector is located at each cylinder inlet. In single-point systems one or two injectors are located at the throttle body. The throttle body replaces the old carburetor. (Exhibit 11)

Electronic ignition has been standard equipment for many years and is now incorporated in the engine control computers (ECC). Several variations of ignition spark control exist. Now coming on to the scene are distributorless ignition systems (DIS), which eliminate the mechanical spark distributor. These systems use several small spark coils which are individually controlled by the electronic computer. DIS allows more accurate spark timing and a wider range of spark advance angles. Eliminating the distributor cap ends the danger of cross-firing at large spark advance angles sometimes needed in lean-burn fuel/air ratio situations.

EXHIBIT 11

MULTI-POINT FUEL INJECTION


LOGIC MODULE
BRAKE SWITCH
DISTANCE SENSOR
A/C DAMPED PRESSURE CYCLING SWITCH
SPEED CONTROL SWITCH (TURBO I)
NEUTRAL SAFETY SWITCH
POWER LOSS LAMP
DIAGNOSTIC READ OUT TOOL
A/C CUTOUT RELAY
RADIATOR FAN RELAY
HEATED OXYGEN SENSOR
TEMPERATURE SENSOR
CHARGE SENSOR
DETONATION SENSOR
(TURBO II)
(TURBO I)
MANIFOLD ABSOLUTE AND BAROMETRIC SOLENOID
AUTOMATIC IDLE SPEED MOTOR
POWER MODULE
THROTTLE POSITION SENSOR
DISTRIBUTOR
IGNITION REFERENCE PICKUP
FUEL SYNCH. PICKUP
IGNITION COIL
ALTERNATOR
FUEL INJECTORS
IN TANK FUEL PUMP
SPEED CONTROL SERVO (TURBO I)

Electronic voltage regulator controlling the battery charging function has been standard for many years and is now incorporated into the engine control computer of Chrysler vehicles. (Exhibit 12).

Car-makers are now investigating an **electronic noise-cancelling muffler** which produces equal but opposite sound waves to those coming out of the engine's exhaust (monitored through a microphone). By allowing the removal of conventional muffler, back pressure will be significantly reduced. One developer, Noise Cancellation Technologies Inc/Walker Manufacturing Co (Tenneco Automotive), is claiming a 5% increase in fuel economy and horsepower as well as 25-30% weight saving on the muffler system – to be available in 1994. Lotus' adaptive noise cancellation system, based on TI's TMS320DSP, does not concentrate on the noise source; instead it is designed to cancel the sound once it reaches the interior.

Computer-controlled throttle for motorcycles, called EXUP (exhaust ultimate power valve), has just been introduced by Yamaha. By installing a movable '"throttle" in the exhaust system, the unruly waves of positive and negative internal pressure have been largely tamed. A crescent-shaped valve, located in the collector between exhaust pipes and the muffler, is opened and closed by an electric motor connected to an engine speed sensor; the setting is controlled by a microprocessor with software containing optimal openings developed from dynamometer studies.

b) Transmission Control

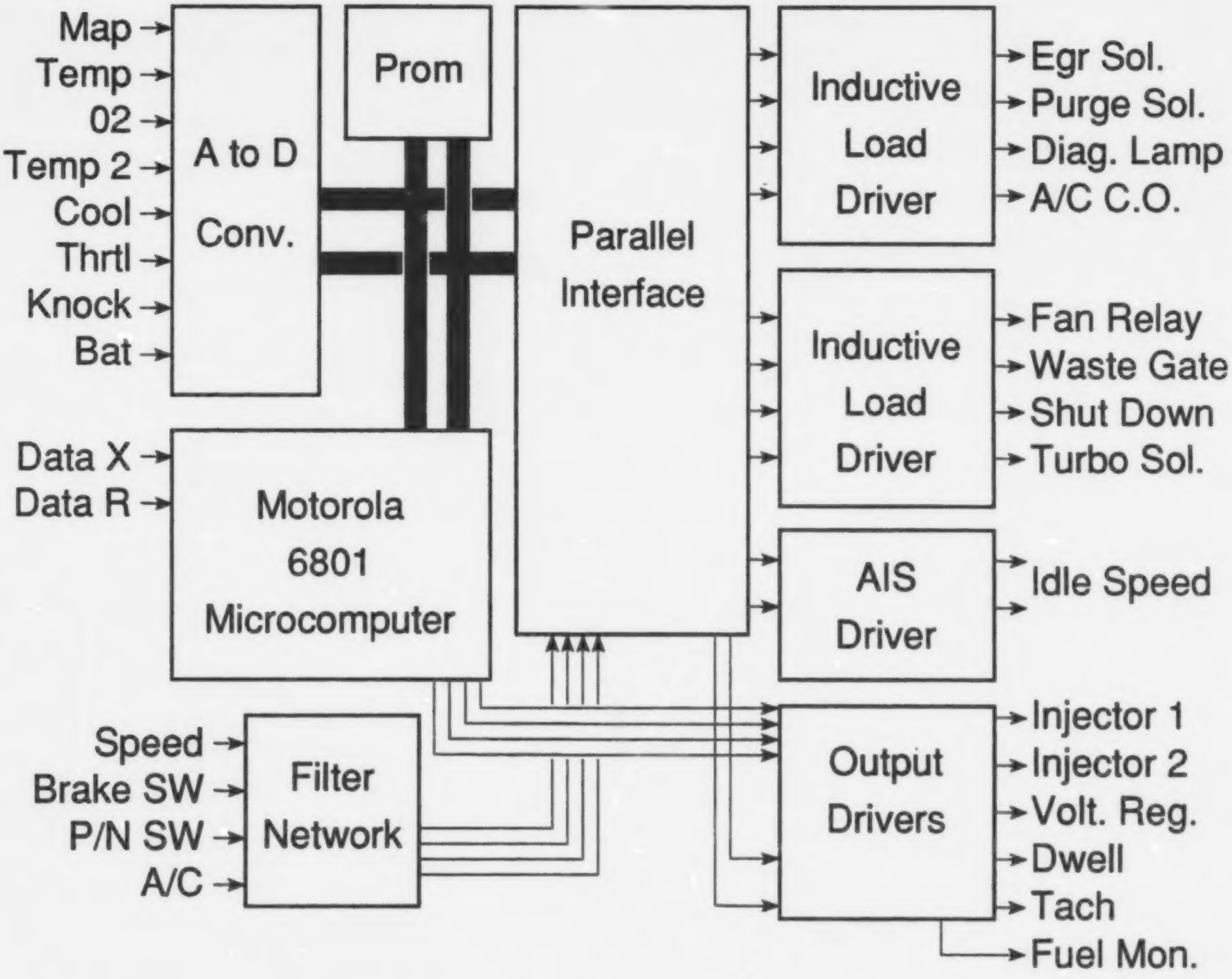
Automatic transmission control system controls the shifting of the transmission by operating electronically controlled hydraulic valves at the appropriate speed and work load of the vehicle. The work load of the transmission drive train is a function of the vehicle speed and the engine's RPM and air flow. The transmission controller normally measures vehicle speed and obtains engine RPM and work load from the Engine Control System via the data link. The driver's inputs are received from the throttle and the shift lever; i.e., park, reverse, neutral, drive, second or first gear. Overdrive modes are also available. (Exhibit 13)

In the modern electronically-controlled transmission, the shift lever signals are electrically communicated to the transmission controller over the data link. Chrysler's new four-speed electronic overdrive automatic transaxle offers improved fuel economy and smoother shifting action. Future models will offer driver-selected economy, power and manual modes.

The Europeans have also marketed an electronic clutch for manual transmission vehicles. The electronic clutch allows the driver to shift gears without stepping on a foot operated clutch pedal. The French Valeo system is the simplest; it uses an electric

EXHIBIT 12

CHRYSLER ENGINE CONTROL COMPUTER


Map
Temp
02
Temp 2
Cool
Thrtl
Knock
Bat
A to D
Conv.
Prom
Parallel
Interface
Inductive
Load
Driver
Egr Sol.
Purge Sol.
Diag. Lamp
A/C C.O.
Inductive
Load
Driver
Fan Relay
Waste Gate
Shut Down
Turbo Sol.
Data X
Data R
Motorola
6801
Microcomputer
AIS
Driver
Idle Speed
Speed
Brake SW
P/N SW
A/C
Filter
Network
Output
Drivers
Injector 1
Injector 2
Volt. Reg.
Dwell
Tach
Fuel Mon.

Tach

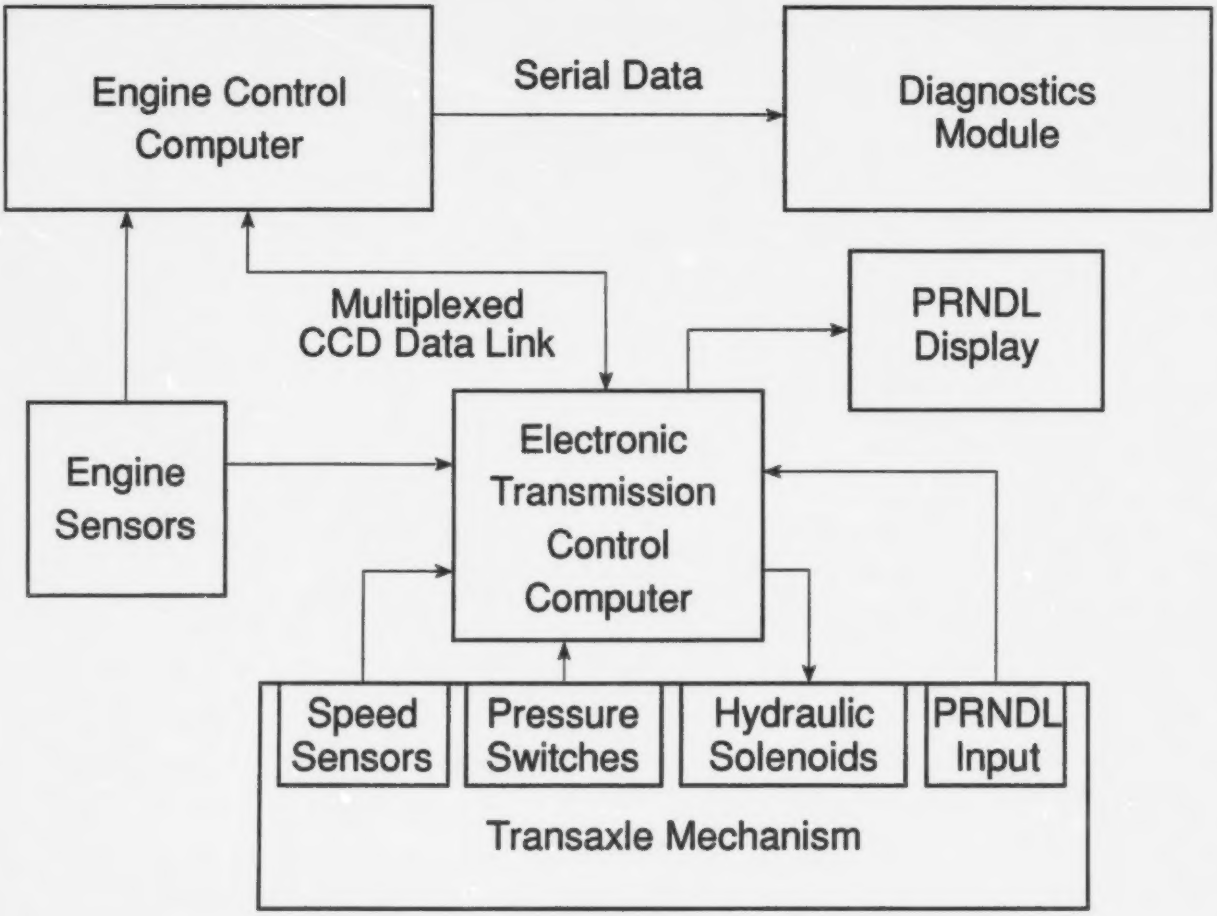
Key:

A to D Conv. = analog to digital conversion
PROM = programmable read-only memory
Data X/R = data transmit/receive
Egr Sol. = exhaust gas recirculation solenoid

P/N SW = park/ neutral switch
A I S = automatic idle speed
A/C CO. = air-conditioning cut-off

EXHIBIT 13

ELECTRONIC TRANSAXLE CONTROL SYSTEM DIAGRAM


Engine Control Computer
Serial Data
Diagnostics Module
Multiplexed CCD Data Link
PRNDL Display
Engine Sensors
Electronic Transmission Control Computer
Speed Sensors
Pressure Switches
Hydraulic Solenoids
PRNDL Input
Transaxle Mechanism

Key:

CCD = multiplexed Chrysler collision detection data link
PRNDL = park/reverse/neutral/drive/low

motor to operated the clutch mechanism. An electronic control module receives engine speed data, transmission input and output shaft speed data and uses that information to compute when to engage the clutch so that a smooth synchronous gear meshing occurs.

c) 4-Wheel Drive

Automatic 4-wheel drive systems are also using electronics to control their engagement and dis-engagement action. Off-road and farming vehicles are frequently equipped with auxiliary power-take-off units, and electronic remote controls and safety interlocking circuits are being incorporated into these accessories.

2.2.3 Chassis Systems

a) Braking

Anti-lock braking systems (ABS) are now available to optimize the braking efficiency of the vehicle and to avoid the loss of directional steering due to skid. These micro-computer controlled braking systems monitor the rotational velocity of the wheels and derive angular acceleration data for each controlled wheel. The computer uses the wheel acceleration and deceleration data to compute the correct amount of hydraulic brake pressure required to optimize the braking and avoid wheel lock-ups which cause skids. Locking up the rear wheels at high speed will almost guarantee a violent skid and it is not unusual to see vehicles spin completely around during a panic braking situation on slippery roads. (Exhibit 14)

With the wheels instrumented for ABS, it is also possible to offer traction control, an automated anti-slip feature for the driven wheels during vehicle acceleration on slippery surfaces. **Traction control** can be extremely effective even on glare ice. Drivers in the northern latitudes will really appreciate this feature when it becomes available. When the majority of cars finally acquire these features of ABS/traction control, the number of winter accidents should be substantially reduced. Anti-lock brake systems are currently marketed for controlling two wheels or all four wheels. ABS systems cost around a thousand dollars today. Incorporating traction control will add another two or three hundred dollars. These prices should drop in half as volumes increase and ABS/traction control systems should be available in the early 1990s for around five hundred dollars. (Exhibit 15)

Specialized anti-lock or anti-skid braking controls are also used on trucks and have been on military and commercial aircraft for many years. Illustrations of the Bosch ABS 2U and ABS/ASR systems are included in Appendix C. As of February 1990, 22 automakers (covering 79 basic models) and 9 commercial vehicle manufacturers are installing the Bosch systems in U.S., Europe, Japan and Korea. In West Germany

EXHIBIT 14

BRAKING FORCE, TRACTION AND SIDE FORCE
versus
SLIP

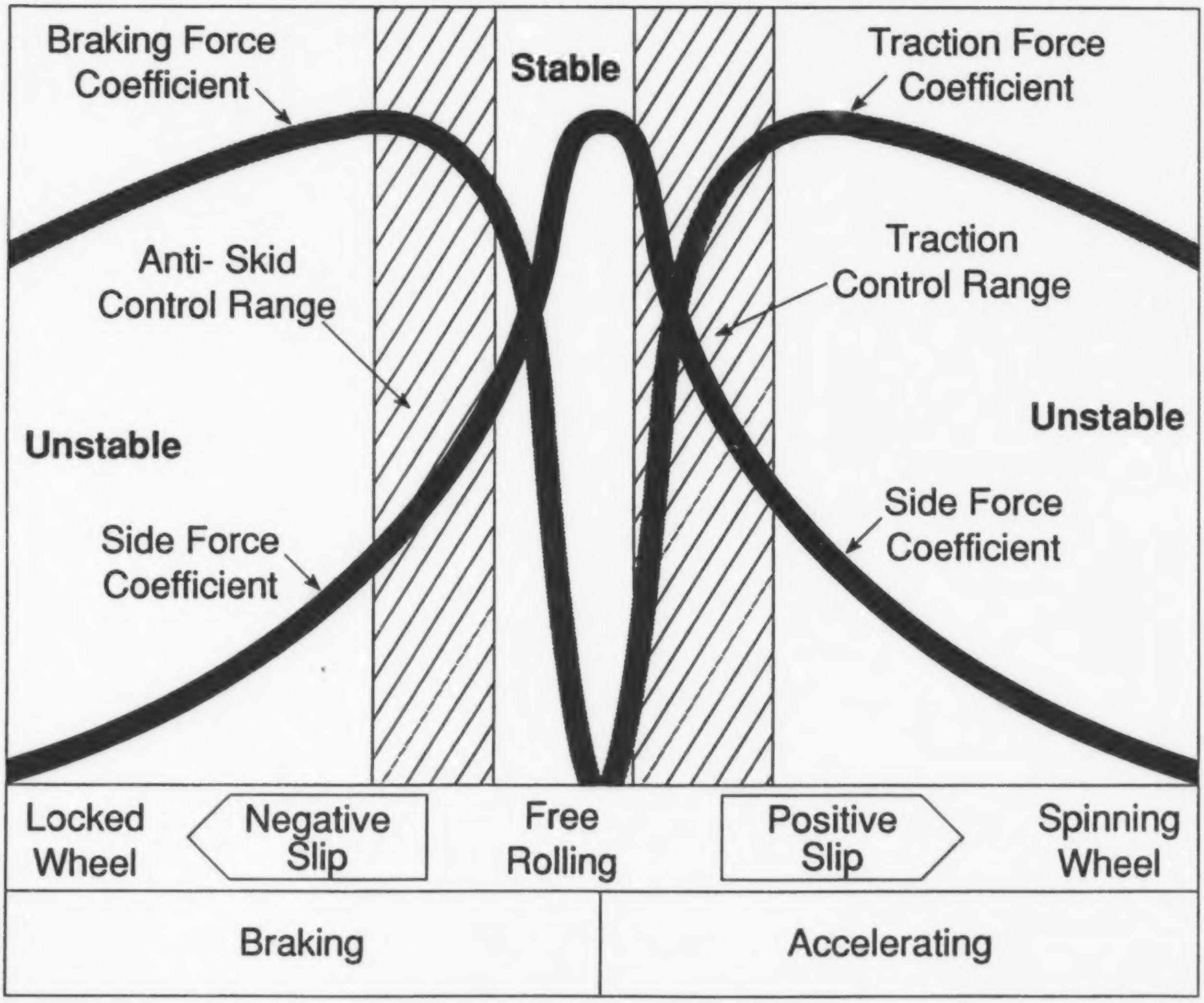
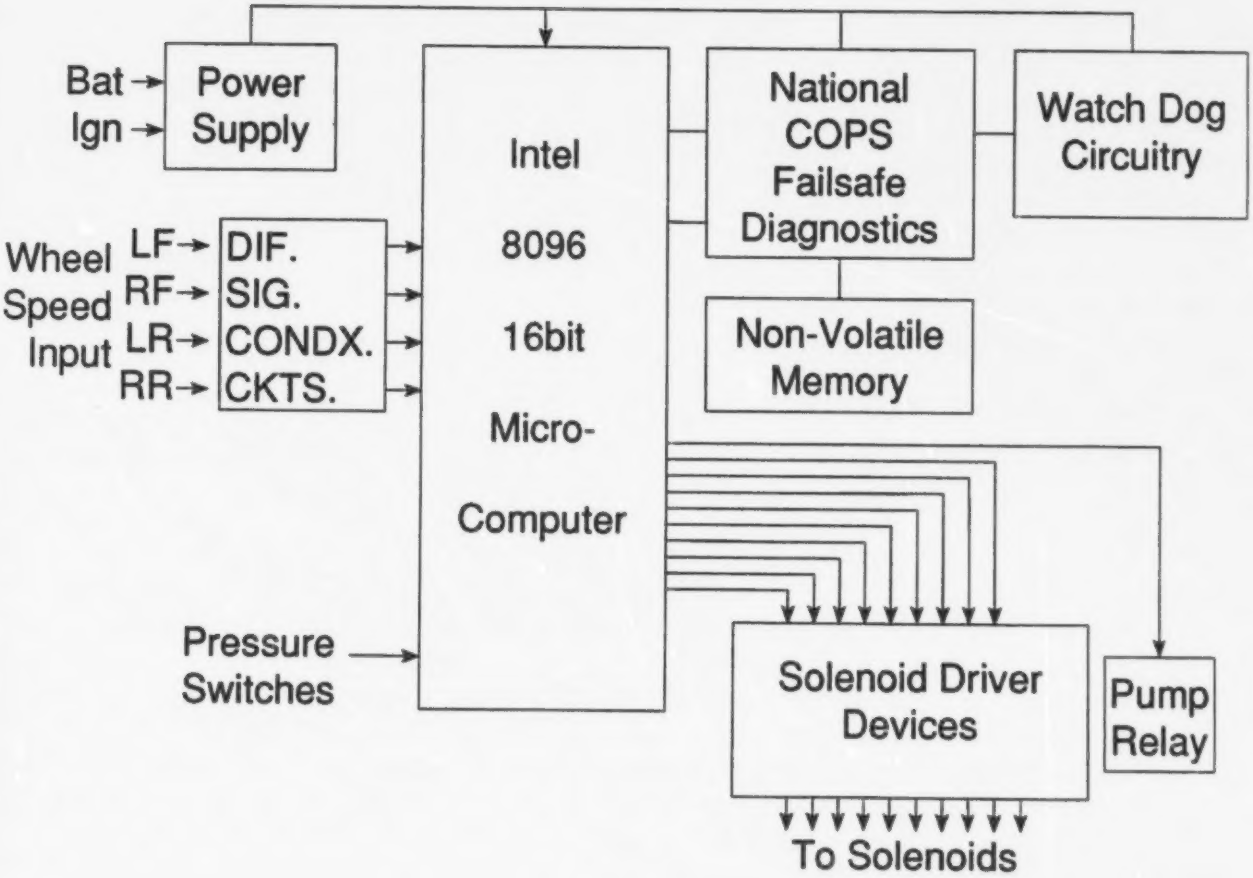

Braking Force Coefficient
Stable
Traction Force Coefficient
Anti- Skid Control Range
Traction Control Range
Unstable
Unstable
Side Force Coefficient
Side Force Coefficient
Locked Wheel
Negative Slip
Free Rolling
Positive Slip
Spinning Wheel
Braking
Accelerating

EXHIBIT 15

ANTI-LOCK BRAKE CONTROL SYSTEM COMPUTER



Bat
Ign
Power Supply
Intel 8096 16bit Micro-Computer
National COPS Failsafe Diagnostics
Watch Dog Circuitry
Wheel Speed Input
LF
RF
LR
RR
DIF. SIG. CONDX. CKTS.
Non-Volatile Memory
Pressure Switches
Solenoid Driver Devices
Pump Relay
To Solenoids

Key:

DIF.
SIG.
CONDX.
CKTS. = diferential signal conditions circuits

COPS = National Semiconductor control oriented processor series failsafe diagnostics

25% of new cars are equipped with ABS, the Western Europe total is 10%, in U.S. and Japan only 3% at present time.

Radar braking for collision avoidance has been demonstrated in several prototype installations and will eventually find application in production passenger cars. Product liability is a major factor deterring the automotive manufacturers from serious consideration of this category of product. An alarm version, signalling the driver to brake, will probably be marketed in advance of any fully automatic braking version. Radar systems are also being investigated for use with electronic cruise control systems to provide an automatic safe separation distance from the car in front. This is sometimes referred to as headway control or station-keeping radar. Both microwave and solid-state laser radar techniques are being investigated.

b) Suspension

Suspension control systems use micro-computers to control servo-motor driven orifices inside the vehicle's shock absorbers thus allowing the suspension to be soft or firm at the driver's wish. Some of these systems provide a load levelling feature to allow the vehicle to be levelled with abnormal cargo or passenger loads. Active suspension control systems incorporate additional sensors to measure vehicle accelerations so that the suspension can adapt to minimize vehicle roll (tilt) during fast turns.

Sonar, IR optical, microwave techniques, can be used to scan the road surface thus providing the additional benefit of road surface adaptability, modifying the firmness of the vehicle suspension to changing road conditions. These adaptive active suspension systems are very expensive and are currently limited to specialty sports car vehicles. (Exhibits 16a and 16b)

Aerodynamic devices such as air spoilers which automatically activate are being added to specialty vehicles such as Porsche's 911 and V.W.'s new Corrado.

c) Steering

Variable-assist power steering control is an important newcomer for the passenger car market and should become quite popular as the public experiences its performance. By controlling the power as a function of vehicle speed, the steering can become tighter at high speed to avoid accidental over-steering and easier at slow speeds to aid in manoeuvring into tight parking spots.

Four-wheel steering is a new feature just being introduced and will also be very helpful in manoeuvring into tight spots. At low speeds the rear wheels are steered out

EXHIBIT 16a

ACTIVE SUSPENSION SYSTEM

Exhibit 9

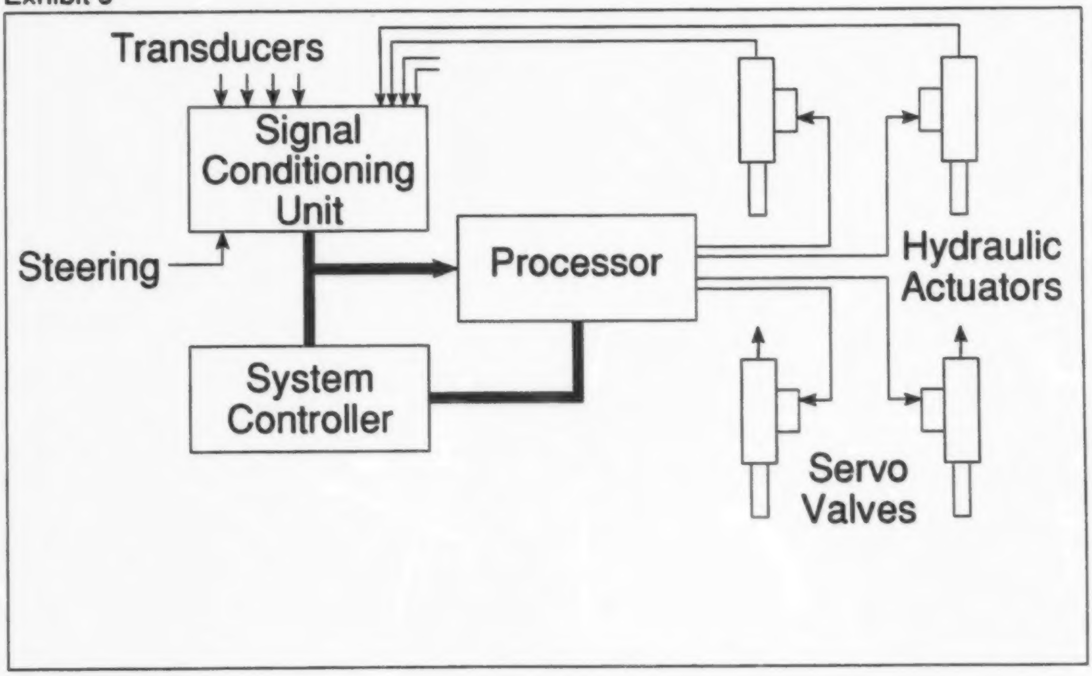
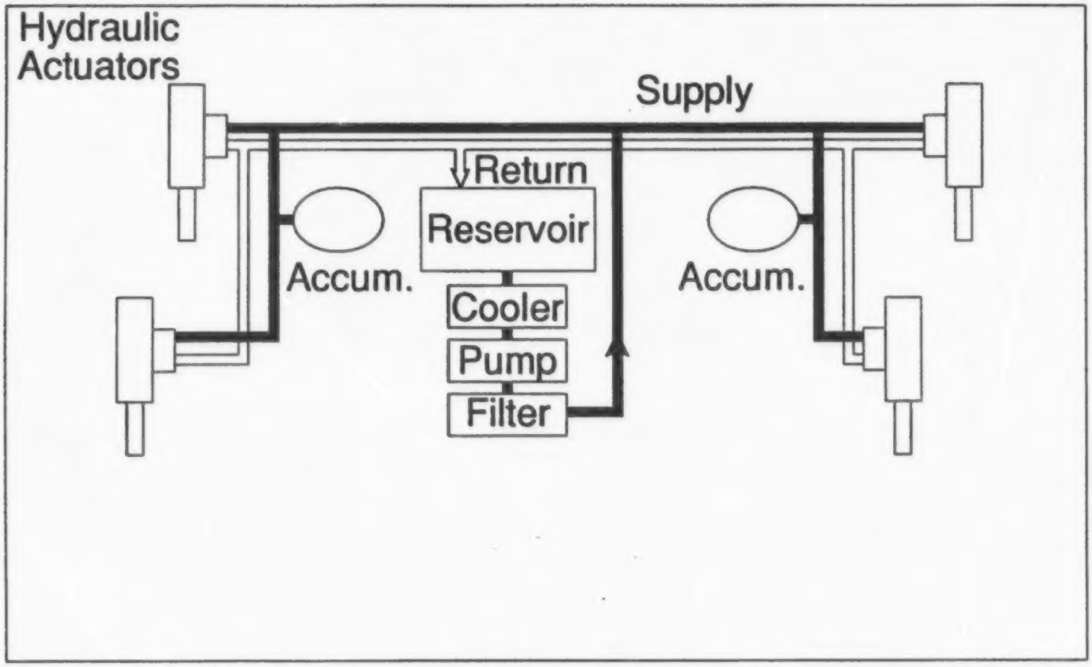

Transducers
Signal Conditioning Unit
Steering
Processor
System Controller
Hydraulic Actuators
Servo Valves

EXHIBIT 16b

ACTIVE SUSPENSION SYSTEM

Hydraulic Diagram


Hydraulic
Actuators
Supply
Return
Reservoir
Accum.
Cooler
Pump
Filter
Accum.

of phase with the front. At high speeds, the rear wheel steering is in phase with the front wheel steering but the rear wheels are turned at smaller angles. Honda and Mazda are currently testing the U.S. market with this option. Since it is mechanically difficult to connect the rear-wheel steering mechanism to the steering wheel, steer-by-wire schemes are being developed. Electrical control signals are sent by wire to actuators that operate the remote steering mechanisms. This arrangement can also be extended to provide remote steering control to trailers. In a few more decades, the reliability of such systems may reach the level that steer-by-wire may be used on the front wheel steering as well.

Development work is underway, by Multidrive (part of David J B Brown Group), to apply electronic steer-by-wire to the rear wheels of trucks – particularly to articulated urban delivery vehicles – to eliminate trailer cut-in thereby increasing their agility in limited spaces and in off-road terrain.

2.2.4 Auxiliary Systems

a) External Lighting Controls

The vehicle's external lighting is in accordance with government legislated minimums. Lamp technology has improved and halogen headlamps offer improved distance visibility for night driving. **Gas discharge lamps** developed by Bosch, which have a slightly blue coloured light, are undergoing extensive field trials in Europe. Each headlight has a compact electronic control unit which supplies the arc-striking voltage (of 5000-12000 V) and regulates power consumption.

To secure maximum performance from the driving lights, dirt sensors can be installed to operated an automatic headlight cleaning unit. The degree of dirt is measured by an infrared ray radiated from the lense; the more dirt, the more light is reflected and registered by a photodiode. To limit water consumption, the (Bosch) microprocessor monitors maintenance of the minimum pauses between cleaning cycles and with the aid of a daylight sensor checks whether driving is taking place in daylight.

Vertical aim controls (VAC) – which can be manual (driver adjusted) or fully automatic using electric servo-motor, hydraulic or pneumatic adjustment (reserved for cars with expensive fittings) – are designed to reduce glare caused by low beams that have been set too high (the most common reason) or that are temporarily pointing too high because of rear heavy loading of the vehicle.

Side markers and cornering lights are also beneficial. After-market versions of the **high-centre stop light** include extra features of green while accelerating and yellow while coasting. Some of them also provide more noticeable turn signals.

The vehicle monitoring systems need to detect faulty lamps and several systems on the market are doing so. GM is using multiplexed wiring to control the external lighting circuits of some of its car-lines. The headlamps can be automatically turned-on in low-light conditions and can be inter-connected to be on whenever the windshield wipers are needed. (Day-time driving lights will be required in Canada in 1990.)

b) Window Controls

Tinted glass, window defrosters and power windows are common options on today's passenger car vehicles. Electrically powered sun-roof windows are also offered on some premium vehicles. Power window controls are now being enhanced to allow lowering by a momentary touch of the down-button. Pressure sensitive strips can be added to allow automatic closing as well. These would act like the elevator doors that automatically re-open if an arm is in the way. These are technically feasible now, but car makers feel that the costs do not yet warrant the product offering. **Rear-window defrost systems** are quite popular and this feature is now being extended to the front windows. The heating element in rear-window systems has also been used as a radio antenna by some Japanese car-makers

Liquid-crystal type electrochromic substances are also being investigated to provide **variable light transmission** to window glass. Ford's version, called "Switchable Privacy Glass," uses LCD technology to adjust transparency from fully transparent to nearly opaque. One estimate for this option in Canada (perhaps in 1994) suggests a price of $750; i.e., this technology must be further refined (made cheaper) before it will be used to any significant extent in production cars.

University of Guelph's (Prof Jim Stevens) **smart window**, which will regulate the transmission of radiant energy, is built of two pieces of glass coated on the inside with a electrochromic material that makes the glass surface conductive. This layer will colour (tint) and bleach as charged ions move through it; in the middle, a solid electrolyte will provide source of ions. The system will use a small power source and sensing device to tell the window whether it is dark or light. In the bleached state, 80% of sun's radiant energy is allowed through; in the tinted state, 20%. Other coatings can be added to make the window selective as to the amount of ultraviolet, visible or heat radiation passing through it.

c) Vision Enhancement

Fog penetrating and **low-light vision systems** are also being investigated by developers outside the automotive industry and may eventually enter the passenger car via the after-market. Low-light-level infra-red vision systems have been developed for surveillance and military applications. Night vision TV systems are also marketed for industrial security surveillance. The automotive systems are expected to improve night vision (of a person standing) from a typical 90 to some 500 metres. This could make an important contribution to road safety: some 55% of traffic fatalities occur at night.

A variety of monitoring **devices to assist backing-up** are available on the after-market. These range from sonar scanners, detecting obstacles behind the vehicle, to rear television cameras viewing rear area blind spots. TV rear view systems are offered as optional equipment for motor home recreational vehicles.

Sonar and solid-state laser devices are being investigated for use as **blind-spot monitors**. One concept uses ultrasonic sonar to scan the left and right rear quarter areas and to indicate the presence of another vehicle by lighting a red light emitting diode (LED) at the appropriate edge of the conventional rear view mirror.

Electronic rear-view mirrors which automatically activate to avoid the glare of high beam lights from an over-taking car were offered in an electro-mechanical form some years ago. Fully electronic versions are now available and offer greatly improved performance. These new automatic mirrors use an electrochromic material to darken the mirror when offending light strikes the photocell sensors.

d) Occupant Safety Restraints

Motorized passive restraints assure that seat belts are used. **Air bag and active restraint systems** are more complex requiring a sophisticated control system and accelerometers to detect the impact and to activate the air bags and tighten the motorized seat belts; the air bag system is activated and the bag filled with nitrogen within 60 ms (it takes 100 ms to blink an eye). Bendix-Atlantic Inflator Co's hybrid air bag inflator, offered in addition to sodium azide systems, uses a solid propellant and argon (an inert, nontoxic gas). Air bags are single-use devices and need extensive re-servicing after use. (GM will install air bags in 13% of cars in 1990.)

Automatic head-rests for rear-seat passenger may be developed in the future to provide maximum rear-view visibility for the driver (when nobody is sitting in the back; these head-rests would automatically rise from the seat back when passenger presence is sensed at the seat (or when requested by a rear-seat passenger). At present, hardly any North-American cars have head-rests in the back – making whiplash likely to rear-seat passengers in vehicles rear-ended at even low speeds.

e) Electrical Power

The conventional alternator and car battery is being overwhelmed by the multitude of electrical and electronic systems being incorporated into passenger car vehicles. The wiring harnesses are also becoming quite bulky and difficult to install or service.

24/36/48 volt systems are being investigated to provide the growing power demand and to keep the wire diameters within reason. Voltages in excess of fifty volts represent a shock hazard that the car-makers would prefer to avoid. Twenty-four volt systems are already used by some truck fleets and most military applications. Some car-makers are looking at hybrid combinations where both 12 V and 24 V are available. The vehicle's alternator can be easily modified to produce higher alternating current voltages, and some manufacturers are already experimenting with AC operated accessories.

Multiplexed wiring systems are currently being incorporated into some vehicles to reduce the size of the wire cable bundles installed. Multiplexing means the time-sharing of wires; a common power wire can deliver power to a number of lamps for example. A separate wire, fibre optic cable or data link can send control codes to remote lamp control modules telling them to connect or disconnect themselves from the power wire or bus. Diagrams for one multiplexing system (General Instrument's AUTOLAN), which is suitable for use in high speed real time control (Class C), are presented in Appendix C. The proposed definition for Class C requires that repetitive and bursty data transfers are possible, handshaking can be implemented, more than 10 nodes can be handled, latency is less than 5 ms, bus rate is 4 M bits/s, and that it can be used as a Class B and Class A system.

Multiplexed wiring will become commonplace as the complexity of automotive electronic systems continues to grow. The 1987 Delphi IV Forecast and Analysis of the U.S. Automobile Industry concluded that 5% of 1990 vehicles would include multiplexed wiring and that this usage would grow to 20% by 1995. This may be a pessimistic forecast and a more rapid growth may be anticipated.

Solar panels for battery charging and for operating ventilation fans are already available on the after-market for cars and for recreational vehicles. Modern solar-cell panels combined with deep-discharge cycle batteries and microcomputer controlled battery charging regulators are already finding a market in the recreational boating arena.

f) Individualized Comfort and Convenience

Comfort and convenience systems are another category of products finding their way into the passenger car market. Memory power seats with his and her memory positions are an example. Six-way adjustable seats with lumbar supports are already available as optional equipment. Power mirrors with his/her memory positions fall into the same sub-system. This category of features can be extended to his/her radio channels, steering wheel tilt and heater/air conditioning settings. Specialized applications would include making entry and exit easier for the elderly and handicapped drivers and passengers.

Automatic climate control systems are already available on most premium line passenger cars. Heated seats are being shown on concept cars and are available in Sweden on the after-market. Outside-air temperature monitors are offered on many new cars; these can be helpful by informing the driver of possible icing due to freezing temperatures. Eventually the brake and gas pedal positions may become adjustable to fit the anthropometry of the driver.

Automatic driver identification can be achieved by coded keys or coded magnetic keytags like the cards used at automatic banking tellers.

Voice-recognition systems are being talked about and experimented with and will eventually become optional products for high-cost vehicles. Today's voice-recognition systems are mostly speaker dependent; they have to be taught to recognize the speakers voice patterns. Speaker dependency is not a serious handicap and adds a certain aspect of security as such a system can be used for driver identification. Problems of the voice changes remain. If the speaker has a cold or is excited his voice will not be recognized (a serious flaw in case of an emergency). Cost-effective speaker-independent systems are needed before reliable voice-recognition products can be expected. Reliability will also depend on finding resolutions to technical problems caused by the in-vehicle environment, one of the harshest environments for the voice recognition technology to be applied.

Voice-recognition activated devices would be useful for on/ off actions that do not require continued interaction by the operator. Good applications are door locks, wipers and radio channels. Poor applications are positioning seats, mirrors or setting the radio volume because these require continued participation by the operator to achieve the desired results.

g) Diagnostics and Service Memory

On-board diagnostics are now being added to individual sub-systems and some manufacturers are offering some very extensive systems. California Air Resources Board (CARB) is requiring common on-board diagnostics for emission control equipment by 1994 and a common diagnostics interface for cars. Cadillac's new on-board diagnostic system makes a record of momentary faults or transient failures that occur in any of its major microcomputer controlled sub-systems. With several Ford vehicles, a service bay diagnostic system (SBDS) can be hooked up to the vehicle's on-board computers via a data communication link (DCL) for diagnosing problems at dealerships.

Service-due advisories are available from on-board systems that keep track of vehicle mileage and operating cycles. An exhaust gas recirculation (EGR) valve service is an example that has been legislated. An oil-change-due advisory is available on some GM cars.

Battelle's new on-line **integrated measuring and computer-assisted data processing**, the Efficiency Trend Analysis (ETA) system, is claimed to perform technically accurate measurements of efficiency during the entire life of a vehicle. It compares the power (output) of commercial vehicles using consumption, torque and speed sensors.

Most electronic control systems in production today incorporate some form of self-monitoring and fail-safe modes to provide what is sometimes referred to as "graceful degradation," designed to allow the vehicle to limp into a repair shop where possible rather than leaving the motorist stranded on the highway due to a minor electronic fault. Sometimes a separate sub-system is dedicated to vehicle status monitoring. Chrysler has offered a combined voice and visual monitoring system which monitors some twenty-four separate conditions such as low fluid levels, burned-out lamps, doors ajar, lights on or key in ignition during exiting. These warnings are displayed on an alpha-numeric times square type read-out and also audibly announced with a synthesized voice. Almost every car manufacturer in the world has offered some type of vehicle monitoring sub-system to alert the driver to important or unsafe conditions.

Tire air-pressure monitoring systems have been available for some time on the after-market for heavy-duty trucks. These systems will eventually find their way into the passenger car market. GM's high-tech Corvette offers a low-tire-pressure warning system that continuously monitors the tire pressure while the vehicle is operating. TechniGuidance's system, called entireControl, relays readings to the car's central computer, which will warn the driver with an audible beeper when pressure falls 15 psi below driver-programmed level; in the automatic-fill version, carbon dioxide is automatically added to the tire from a reservoir mounted on the inside of the wheel rim (estimated Canadian price $500-$600). Michelin's system has two microsensing devices positioned on a small pin inside each wheel's rim (including the spare); information on air temperatures and internal pressures is relayed by two antennas to a computer, which will alert the driver as required.

h) Security Systems

Security-alarm systems have been popular passenger car options in high-theft metropolitan market areas. Many of these systems now offer remote beeper features to signal the car owner that his vehicle is being tampered with. They also offer remote controls to allow the owner to beep his car horn or flash the lights. A few such systems also allow remote starting of the engine to warm-up or to air condition as the season dictates. The Delco Electronics's PASS-Key (personalized automotive security system) is encoded with a small resistor pellet that matches an electrical code in the vehicle's black box; if a wrong key is inserted, the starter and fuel systems are disabled. Since 1986 when GM started equipping Corvettes, the number of stolen Corvettes has dropped 45%.

Keyless entry is a related feature that is being offered in some forms on production passenger cars. It is reasonable to assume that the tumbler operated door and ignition locks will someday be replaced by some electronic means. Many hotels and motels are now using programmable magnetic card door keys. GM's remote keyless entry system is standard on some car lines. It consists of a miniature, hand-held radio transmitter that doubles as an ignition keytag. It allows the driver to lock or unlock doors or trunk at a distance of thirty feet and can also activate the interior courtesy lights.

Infra-red transmitters, like a miniature TV remote control are used in some remote keyless entry systems. United Technologies Automotive's system is based on surface acoustic wave (SAW) technology, an advanced method of generating radio frequencies. In addition to the door(s) and trunk, the transmitter's three buttons can operate several convenience and security features such as panic alarm.

2.2.5 Driver Interfaces

Electronic instrument panel system provides the visual display of information to the vehicle operator. The most common type of read-out used today is the blue-green vacuum fluorescent display which is available in the form of digital numerical read-out and analog or bar graph read-out. The illuminated segments of these visual read-outs are controlled by a display driver microcircuit that takes data from a micro-computer chip and converts it into the form required by the vacuum fluorescent display or read-out.

Cathode ray tubes (CRTs), liquid crystal displays (LCDs) and dot-matrix vacuum fluorescent panels are also coming into use. Recently the luminous efficiencies of yellowish green and blue phosphor have been greatly improved (by 130% to 400 cd/mæ, and by 160% respectively); making them available for the 12 V driven VFDs.

These are all **programmable displays** that can read out one kind of information while driving, and another kind while stopped. By localizing application-specific components during design, such display products can be made to fit many different applications. Common design philosophy for the display subsystems is "application independence," which takes into account three design areas: display hardware configuration, the user interface, and the display subsystem interface.

Significant R&D is being devoted to flat screen technology. Plasma, conventional LCD, improved VHC LCD, electroluminescence and matrix-addressed cathodoluminescent display panels are all vying to replace the conventional TV type CRT. In the very high contrast LCDs, a contrast over 1000 can be achieved (by nearly totally eliminating transmittance of light through the background, or "bleed-through").

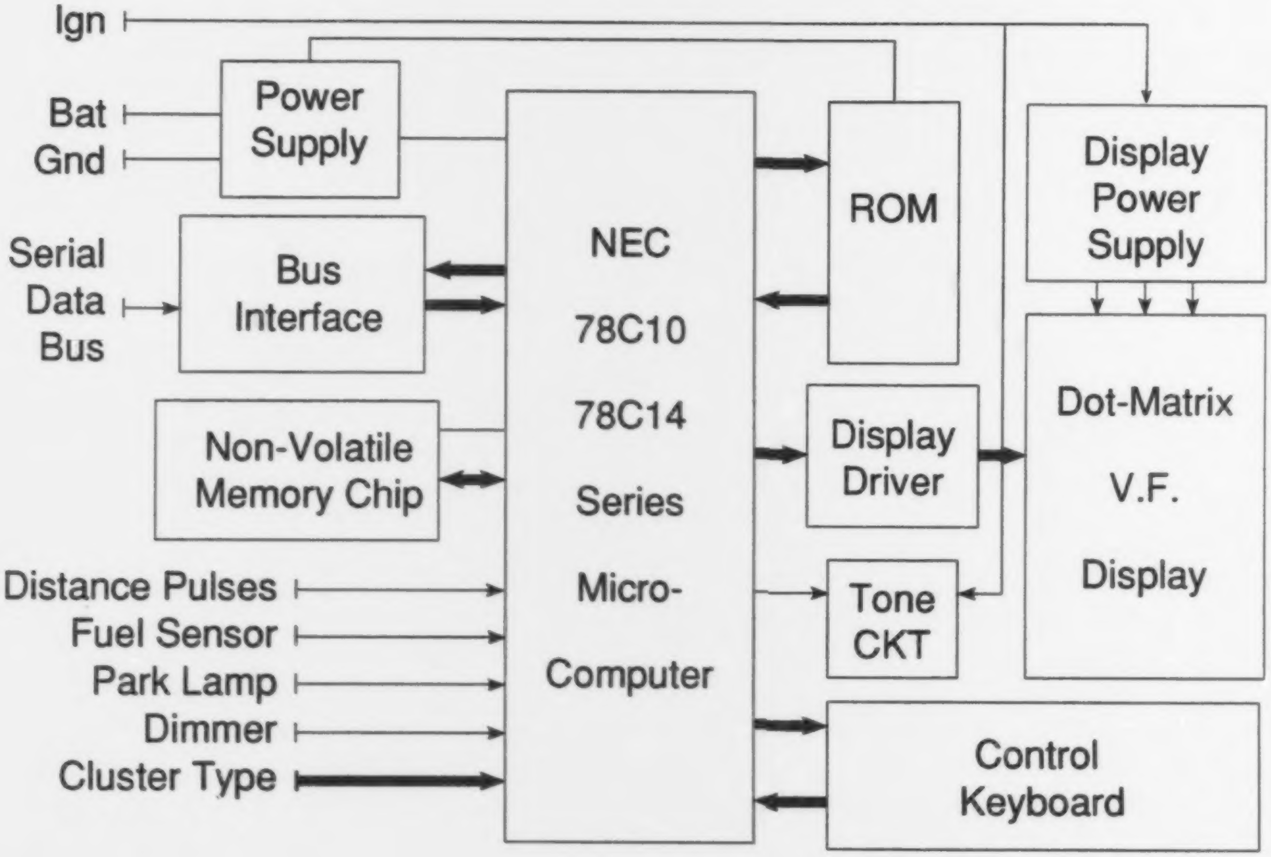
Nippondenso and Toyota have jointly developed a new lighting system for electronic analog clusters which features very sharp white lit pointers with evenly illuminated white dials on a black acrylic face. The pointers are made from thin lightweight "cold cathode discharge tubes" (with xenon gas) combined with circular shaped cold cathode tube installed behind each dial applique.

A colour CRT screen is used as an information centre in the GM Oldsmobile Toronado dash. This optional unit controls the entertainment and climate control systems as well as tracking oil changes and providing a monitor for engine data. (Exhibit 17)

Head-up displays (HUD) are now being introduced by a few car manufacturers to display speedometer data as a virtual image the driver can read without taking his eyes off the road. Some of these new systems also show high beam and turn signal status plus an alert indicator telling the driver to check the standard instruments for an abnormal condition.

EXHIBIT 17

OLDSMOBILE DRIVER INFORMATION SYSTEM MODULE


Ign
Bat
Gnd
Power Supply
Serial Data Bus
Bus Interface
Non-Volatile Memory Chip
Distance Pulses
Fuel Sensor
Park Lamp
Dimmer
Cluster Type
NEC 78C10 78C14 Series Micro-Computer
ROM
Display Driver
Tone CKT
Control Keyboard
Display Power Supply
Dot-Matrix V.F. Display

Key:

Ign / Bat / Gnd = ignition / battery / ground
ROM = read-only memory
Tone CKT = tone circuit
V.F. = dot-matrix vacuum fluorescent display

The electronic instrument panel system receives much of its information from the data links with other sub-systems. Sometimes the micro-computer in this sub-system is used to read switch closures or the operator's commands such as the shift lever setting, the headlamp on/off, the windshield wiper commands or the cruise control settings. The electronic instrument panel system would then make these commands available on the data links. Some vehicle manufacturers use a separate sub-system for handling these driver commands; and limit the instrument panel system to the display or received information. Touch-panel controls and low-travel click switches are being used and these can now be located in convenient-to-reach pods or in some cases on the steering wheel spokes.

The differences in sub-system functions are a matter of the overall **vehicle system partitioning**. The architecture of these sub-systems is partitioned for practical reasons that differ slightly from one manufacturer to another. A single central computer controlling all the functions of the vehicle is technically feasible but is not presently practical. The engine, transmission and driver are physically separated in the real world vehicle; therefore the wiring and the functional complexity of individual controllers is much simpler than that of a single central system. By partitioning the vehicle's control requirements into sub-systems, the engine control computer can become part of the engine, the transmission control computer can become part of the transmission and so on. This reduces the design complexity of each sub-system and permits them to be optimized for their special tasks.

The fail-safe aspects of sub-systems are also more manageable than those of a central system. The use of separate microcomputer sub-systems instead of a single central computer does not invalidate the concept of a central controller. A central controller can take the form of an additional microcomputer performing the task of systems integration. It can dictate specific modes of operation for the microcomputers in other sub-systems and can coordinate the communication between sub-systems by managing the data links. It can also handle diagnostics.

Driver performance monitoring systems have been demonstrated in some concept vehicles and a few after-market devices are available. The idea of detecting a drug or alcohol impaired driver with a keyboard test has been modeled. It is doubtful that many such driver skill evaluation devices will appear in production passenger cars without the pressure of some government legislation.

Concepts to detect driver fatigue and to alert a nodding sleepy driver have also been demonstrated. One technique utilizes a computer to monitor the small corrective steering wheel movements that are characteristic of an alert driver. A simple aftermarket product clips onto your eye glasses and sounds a beep when the drivers head tilts for too long. A fine idea if the driver remembers to put it on. Generally speaking, effective driver performance monitoring may be more difficult to achieve than electronically controlling the cars' systems; nevertheless, this represents an area to which more research and development should be devoted.

2.2.6 Feedback Control Systems

Control theory grew out of World War II with the rapid development of electronically controlled servo-mechanisms used to stabilize and point anti-aircraft guns, searchlights, etc. The M.I.T. Radiation Laboratory Series of books, sponsored by the Office of Scientific Research and Development National Defense Research Committee, documented this early work.

a) Basic Servo Loop

The birth of the low cost Integrated Circuit Operational Amplifier brought forth an explosion of industrial applications of feedback control systems. A basic servo loop is shown in Exhibit 18a. The concept is simple. A differential summing point detects the error voltage between the desired value and the value fed back by the position sensor at the output shaft. The high gain amplifier multiplies this error voltage to a large enough value to drive the actuator motor. The actuator motor moves the output shaft until the feedback voltage exactly cancels the desired value at the differential summing junction. The error voltage is then zero and the amplifier output is also zero so that the actuator motor has no voltage to cause it to run.

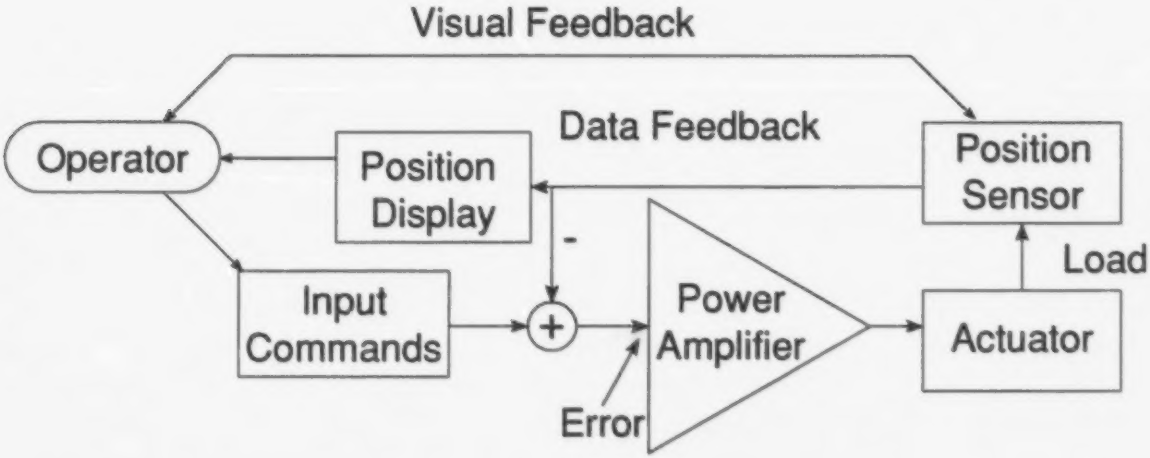
In the real world, the theory is more complex because of the issue of stability. Should the output shaft coast beyond the desired null position, the error voltage would reverse and the servo-loop would drive the actuator back in the opposite direction. Most servo mechanisms include a velocity feedback term to avoid such servo-loop hunting. The velocity feedback term can be derived by taking the derivative of the feedback position relative to time. The stability criteria of servo-mechanisms is well documented in modern text books.

b) Digital Microcomputer Position Control

Most feedback control systems today use digital techniques made possible by the integrated circuit microcomputer devices. A digital microcomputer position control system is presented in Exhibit 18b. Stability issues in the digital servo-loop are mathematically more complex due to the fact that digital systems are not time-wise continuous. Since the digital microcomputer operates a sequence of instructions, it

EXHIBIT 18a

BASIC POSITION CONTROL SERVO LOOP SYSTEM


Visual Feedback
Data Feedback
Operator
Position Display
Position Sensor
-
Load
Input Commands
+
Power Amplifier
Actuator
Error

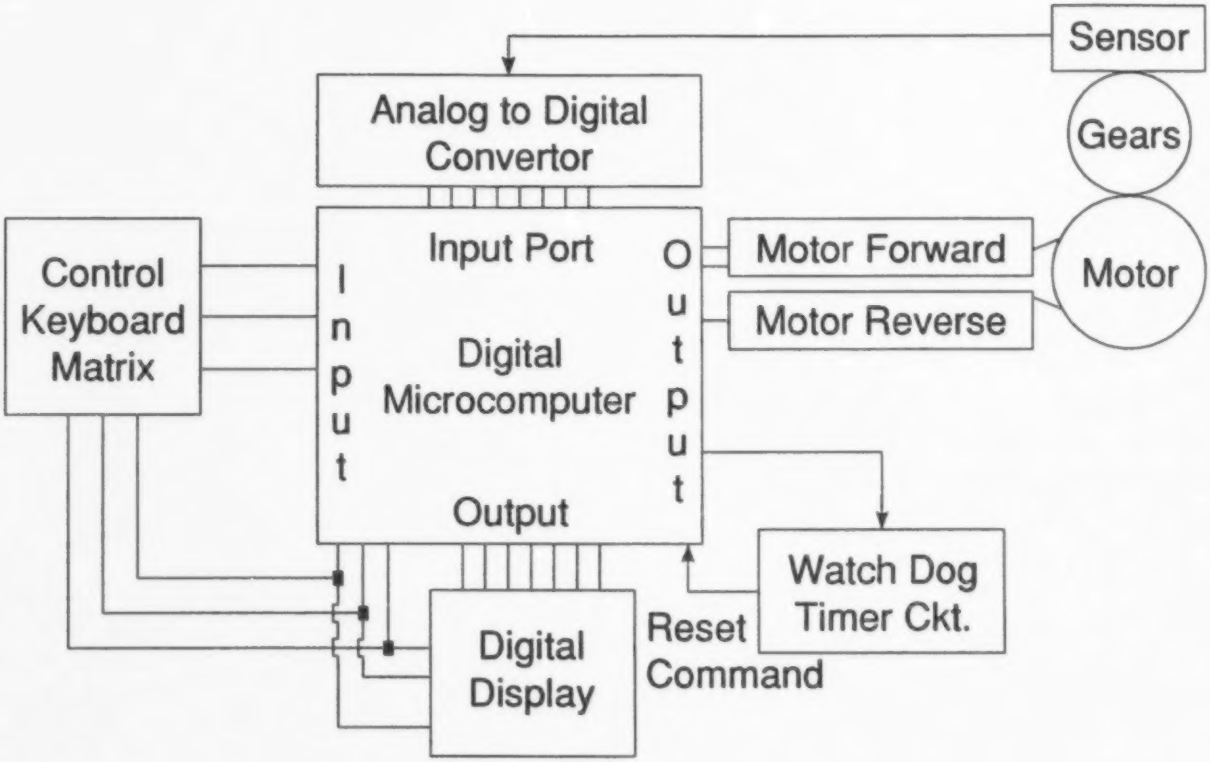
Operator observes position and display and modifies command as necessary

Servo Control Loop

The error between desired and actual is amplified causing the actuator to move the actual position until the error is zero

EXHIBIT 18b

DIGITAL MICROCOMPUTER POSITION CONTROL SYSTEM


Sensor
Gears
Analog to Digital Convertor
Input Port
Input
Digital Microcomputer
Output
Output
Motor Forward
Motor Reverse
Motor
Control Keyboard Matrix
Watch Dog Timer Ckt.
Reset Command
Digital Display

only periodically samples the feedback data via the analog to digital convertor. The designer has to make certain that the computer samples the feedback at a suitable data rate to permit reasonably accurate computations of the needed actuator drive outputs.

Failure modes on computer operated feedback control systems are different than those of the differential operational amplifier type. An electrical noise transient can cause a computer to literally lose its mind. The program control register in the computer normally points to the program memory location containing the instruction that will be fetched from memory and executed.

An electrical disturbance might cause the program control pointer register to point to an incorrect location. If this occurs the computer will attempt to execute an erroneous instruction. If the location is within the program memory, the computer may progress through the instruction sequence and begin to function normally on the next loop through the instruction set. If the erroneous location ended up in non-program memory such as a random-access-memory location, the computer could remain insane until reset. The watch dog timer circuit is a feature included in most industrial and automotive microcomputer control applications. The watch dog circuit is normally reset at least once per program loop by one of the microcomputer's programmed instructions. It will reset the computer if the timer fails to be reset by the normally sane computer program.

c) Individual Subsystems

The application of microcomputer control systems to automobiles began with **individual microcomputer sub-systems**, each designed to do a specific stand-alone task. These are accomplished with simple computers, usually 8-bit machines, there is little or no communication between the subsystems and the programmer's job is simply to execute the algorithms necessary for a single subsystem.

As shown in Exhibit 19a, this decentralization ignores the physical interactions that may occur between these subsystems. It is possible to have an engine control computer subsystem managing spark timing and fuel injection while another subsystem manages the transmission. If these two systems are stand-alone systems that only share a little information, they are decentralized. Sometimes this is referred to as distributed intelligence.

d) Centralized Control

Some advocates expect a centralized control scheme as shown in Exhibit 19b. This approach requires that one powerful computer manage all of the systems. This of

EXHIBIT 19a

TOTAL DECENTRALIZATION

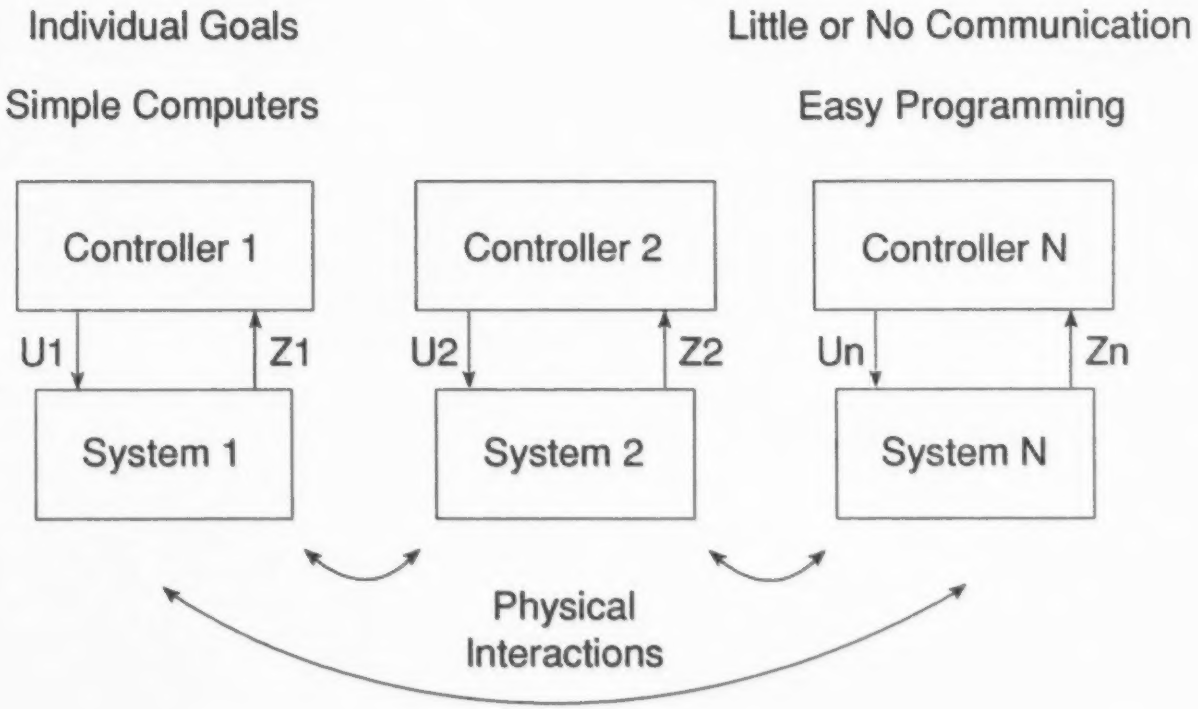
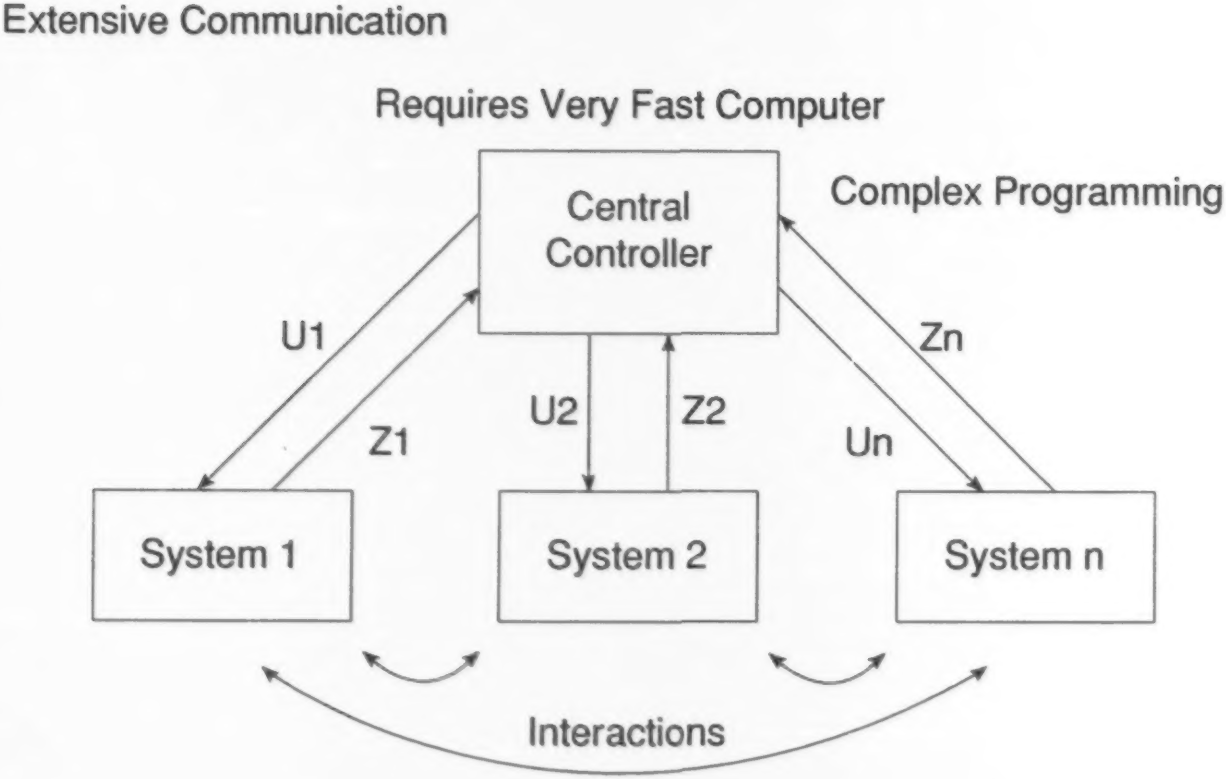

Individual Goals
Little or No Communication
Simple Computers
Easy Programming
Controller 1
Controller 2
Controller N
U1
Z1
U2
Z2
Un
Zn
System 1
System 2
System N
Physical
Interactions

EXHIBIT 19b

CENTRALIZED CONTROL


Extensive Communication
Requires Very Fast Computer
Complex Programming
Central Controller
U1
Z1
U2
Z2
Zn
Un
System 1
System 2
System n
Interactions

course requires extensive communication with sensors and actuators of all of the systems. Keep in mind that these controlled systems are usually at different physical locations within the automobile. A very fast computer would be required to allow reasonable sampling rates at each system being controlled, and the programmer's task would be overwhelming.

e) Hierarchical Control

Much of the engineering community expects an intermediate solution as shown in Exhibit 19c. A hierarchical control scheme retains the distributed intelligence with simple computer controllers at the various system locations. Communication is at a moderate level – and, most importantly, relates to the anticipated physical interactions, eg: tell the transmission controller that the engine control is revving up the engine; tell the engine control that the traction control system is encountering wheel spin. By performing the control algorithms at the local or subsystem level, the computers can remain relatively simple and the programming task can be divided for each subsystem.

An additional computer is added for coordination of the communication between the distributed systems. In more sophisticated applications, this **executive computer** will incorporate an estimator or mathematical model of the expected physical interactions so that the suspension control system, for example, can be informed of an anticipated roll action due to a steering system turning command.

This hierarchical control concept, as applied to a fully integrated automotive system of the near future, is illustrated in Exhibits 20a and 20b. The subsystems not directly related to vehicle motion dynamics are presented in Exhibit 20a; these generally include all of the driver comfort and convenience items. The data bus communications involved with these systems can take place at a slower rate and with a lower priority than those involved with dynamic systems management.

The dynamic systems, which require real-time control and involve high speed data communication requirements, are presented in Exhibit 20b. It is quite realistic to expect that the data bus shown in these exhibits would be separate. It is also feasible to envision two separate executive computers linked together via a third data path.
A summary illustration of the "electronics in the car" (by Bosch) is included as Exhibit 21. The Bibliography of this report (item numbers 32 to 37) contain additional reading into electronic systems for vehicular monitoring and control.

EXHIBIT 19c

HIERARCHICAL CONTROL

Multi-Level

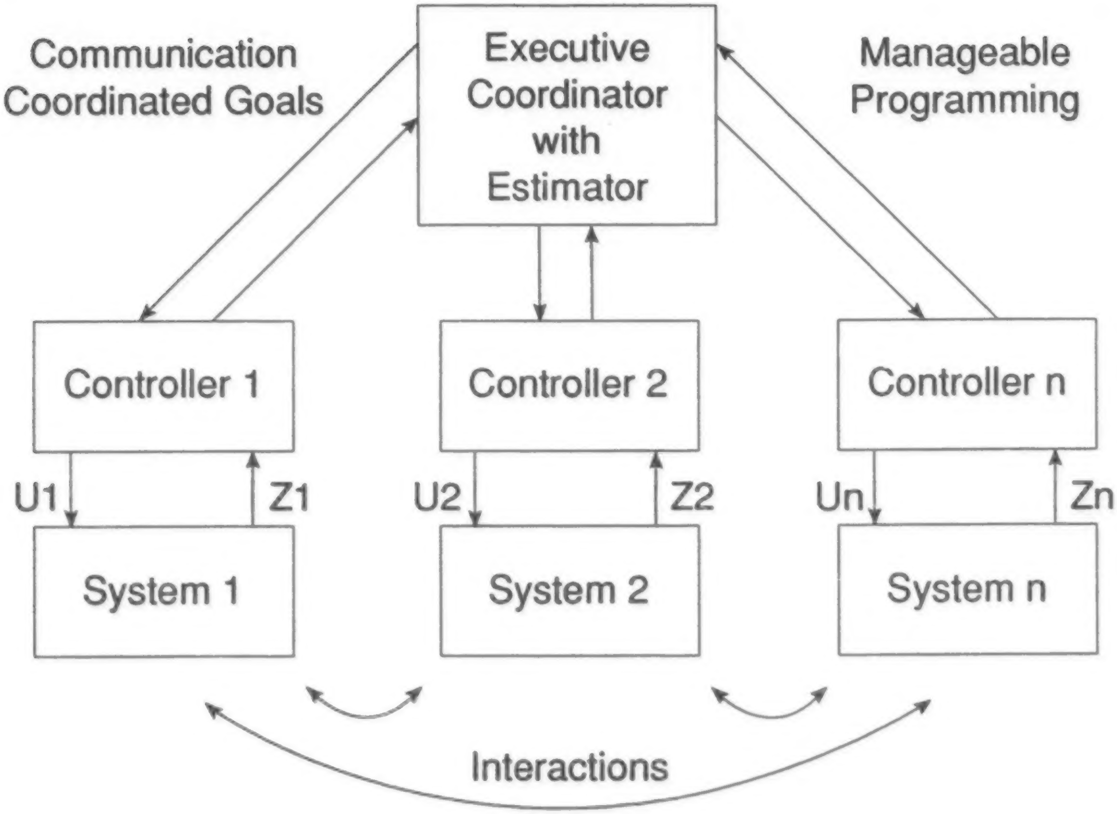

Communication
Coordinated Goals
Executive
Coordinator
with
Estimator
Manageable
Programming
Controller 1
Controller 2
Controller n
U1
Z1
U2
Z2
Un
Zn
System 1
System 2
System n
Interactions

EXHIBIT 20a

VEHICLE MONITORING AND CONTROL

Not Related to Motion

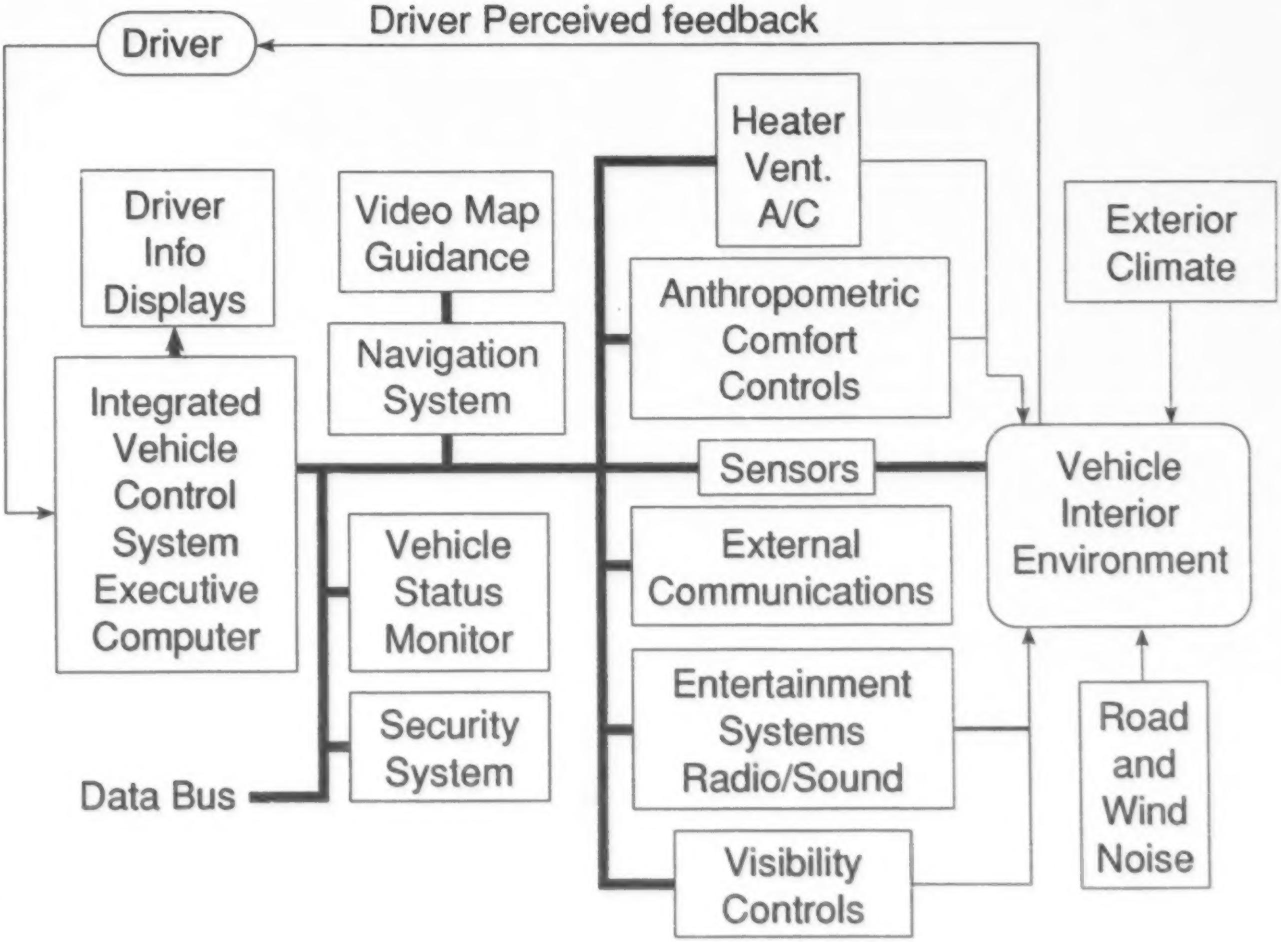

Driver Perceived feedback
Driver
Heater
Vent.
A/C
Driver
Info
Displays
Video Map
Guidance
Exterior
Climate
Anthropometric
Comfort
Controls
Navigation
System
Integrated
Vehicle
Control
System
Executive
Computer
Sensors
Vehicle
Interior
Environment
Vehicle
Status
Monitor
External
Communications
Entertainment
Systems
Radio/Sound
Security
System
Road
and
Wind
Noise
Data Bus
Visibility
Controls

EXHIBIT 20b

INTEGRATED VEHICLE CONTROL

Related to Motion

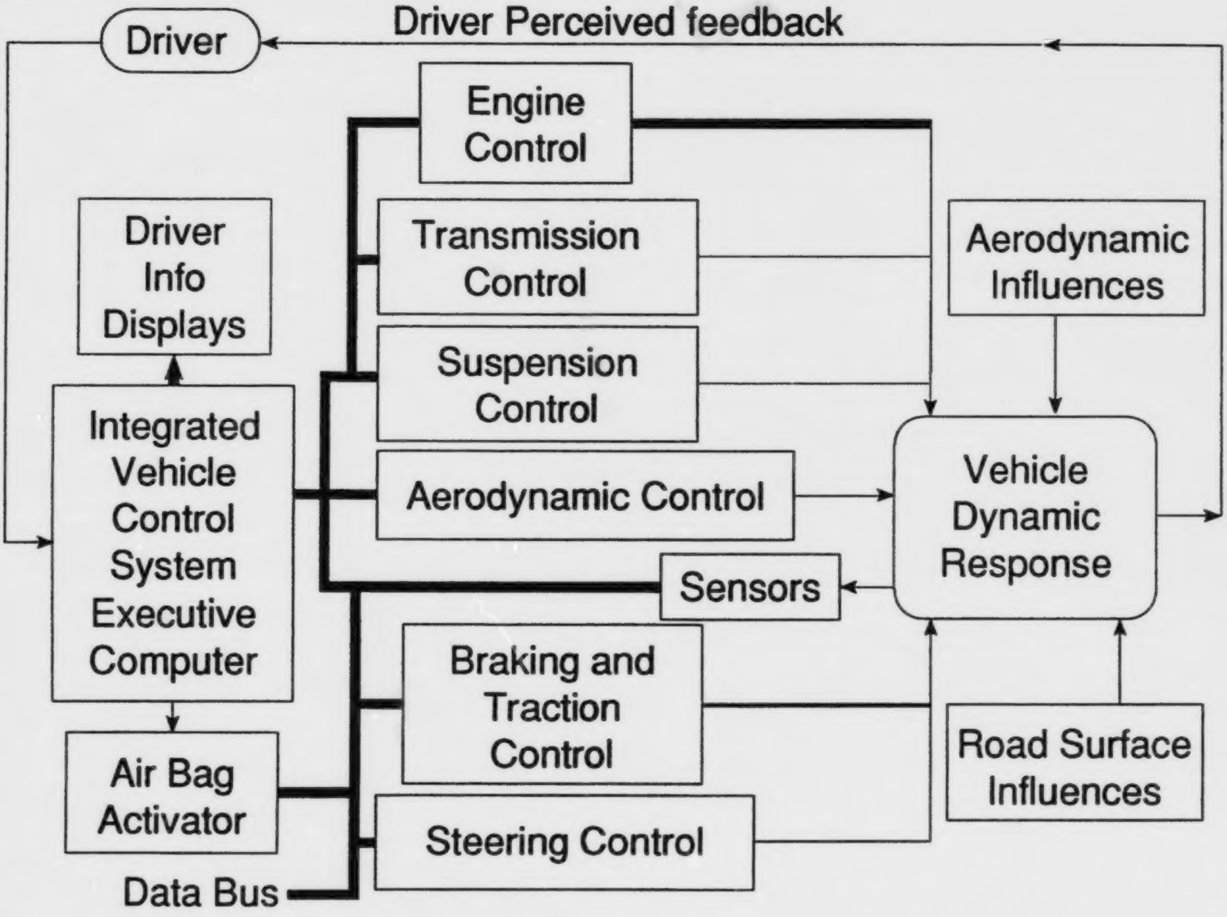
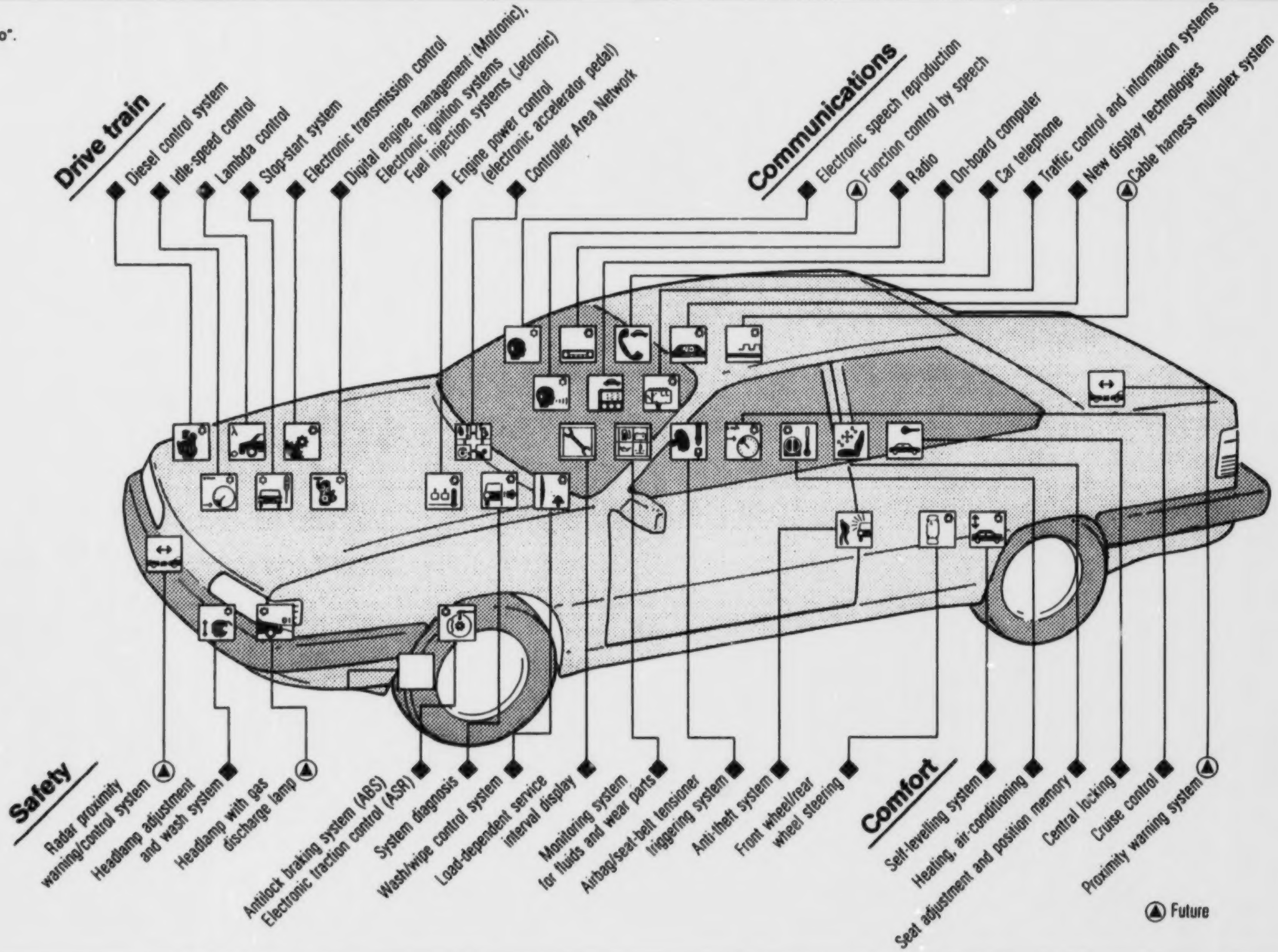

Driver
Driver Perceived feedback
Engine Control
Transmission Control
Suspension Control
Aerodynamic Control
Sensors
Braking and Traction Control
Steering Control
Driver Info Displays
Integrated Vehicle Control System Executive Computer
Air Bag Activator
Data Bus
Aerodynamic Influences
Vehicle Dynamic Response
Road Surface Influences

EXHIBIT 21

ELECTRONICS IN THE CAR

"Bosch Press Photo".


Drive train
Diesel control system
Idle-speed control
Lambda control
Stop-start system
Electronic transmission control
Digital engine management (Motronic), Electronic ignition systems
Fuel injection systems (Jetronic)
Engine power control (electronic accelerator pedal)
Controller Area Network
Communications
Electronic speech reproduction
Function control by speech
Radio
On-board computer
Car telephone
Traffic control and information systems
New display technologies
Cable harness multiplex system
Safety
Radar proximity warning/control system
Headlamp adjustment and wash system
Headlamp with gas discharge lamp
Antilock braking system (ABS)
Electronic traction control (ASR)
System diagnosis
Wash/wipe control system
Load-dependent service interval display
Monitoring system for fluids and wear parts
Airbag/seat-belt tensioner triggering system
Anti-theft system
Front wheel/rear wheel steering
Comfort
Self-levelling system
Heating, air-conditioning
Seat adjustment and position memory
Central locking
Cruise control
Proximity warning system
▲ Future

2.3 Travel Support Systems

2.3.1 Traffic Information Broadcasting Systems

a) Introduction

Traffic information broadcasting systems can potentially play an important role in keeping the motorist updated on current network traffic conditions, enabling him to adapt and re-plan his route as necessary. The systems can be used to warn drivers of various conditions including recurring congestion, short-term holdups caused by traffic incidents, or planned activities likely to cause congestion such as road maintenance and special events. This enables drivers to consider avoiding that particular area, perhaps reducing the general level of congestion and making savings in their own journey time, distance or cost. (A system diagram is shown in Exhibit 22.)

b) Highway Advisory Radio

In the U.S. and Canada, formal traffic information broadcasting is provided by highway advisory radio (HAR) or "audio signing." HAR is a short-range broadcast service provided from low-power transmitters located along the roadways directly to each motorist through his/her standard AM car radio, usually on 530 kHz or 1610 kHz frequencies (either end of the band width).

Fixed signs are installed to advise motorists to tune radio to the AM station to receive traffic, weather or other information. HAR messages are generally recorded for continuous repetition. The message length is adjusted to permit the driver to receive the messages at least twice while passing through the station's coverage zone. Two alternative antenna configurations are used:

- cable radiator antenna: slotted, spiral ribbon or loose braid cable usually imbedded in the roadway (provides a 30 m wide tunnel-like transmission coverage, continuous through actual tunnels, underpasses, between buildings)

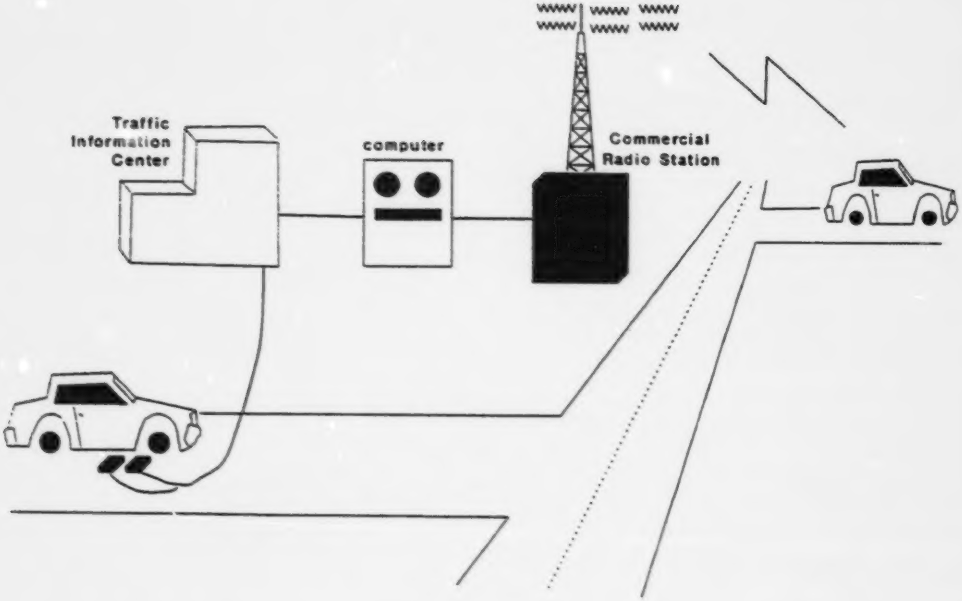
- monopole whip antenna: vertical conductor with a feed to a transmitter and power supply on the ground (provides a spherical transmission, all-directions coverage).

In the U.S., travellers' information stations (TIS) have been authorized, since 1977, to provide this service under rules that limit location, extent of coverage and message content. This authorization, and the rules covering HAR services, are contained within Docket 20509 of Part 90 of the Federal Communications Commission (FCC) Rules and Regulations.

EXHIBIT 22

TRAFFIC INFORMATION BROADCASTING

System Diagram


Traffic Information Center
computer
Commercial Radio Station

HAR can be used to supplement fixed and changeable message signs to advise motorists of maintenance or construction zones, or of specific congested sections (and reasons for the delays) which have been identified by the highway agency's surveillance techniques. This advisory may also include recommendations on specific alternative routes through which to bypass the congested section.

In these instances the HAR facility is preferably installed well upstream from major decision points (e.g., off-ramps), so that drivers have time to think and decide about taking the alternative routes. (Note: this feature makes HAR highly complementary to changeable message signs, as it is seldom practical to install enough (expensive) changeable signs to achieve a similar effect.)

The operating agency should be certain that the alternative route is better (and for how long) than the main route before giving specific recommendations, in order to avoid loosing its credibility with the drivers. The accuracy of the advice is always dependent upon the agency's surveillance capabilities; the information can only be as specific as the real time data collected on all the parallel facilities of each affected corridor section.

There are some, albeit very few, spot applications of HAR in Canada, e.g: in Banff by Parks Canada, at the Blue Water Bridge in Sarnia by Ontario Ministry of Tourism and Recreation, at Lester B Pearson International Airport. In Sarnia each transmission (5-6 min main content + 3-5 min insert), run continuously around the clock and heard within a 9 km radius on 1150 AM, offer advice on Canadian traffic laws, currency exchange, events, weather, and U.S. customs regulations (for returning visitors); at Toronto airport, terminal numbers for each airline, availability of parking, etc. are transmitted.

In most of Canada however, the significant traffic advisory capability – that an HAR system would provide – has been totally missed. The only advisory service is provided by standard AM broadcast stations. They often engage small planes or helicopters for traffic reconnaissance and complement that information by data from the traffic control centre, the provincial and local police, and from the public (by encouraging free en-route call-ins by mobile telephone owners who have an incident site in their view). Even where a formal HAR exists, these radio station traffic reports can present an informal but important complement.

c) Automatic Highway Advisory Radio

In an attempt to overcome some of the limitations of HAR, U.S. FHWA initiated the research and development of automatic highway advisory radio (AHAR). AHAR has several goals which represent a significant improvement over existing HAR:

- eliminate the need for advance roadside visual signs which inform the motorists of an HAR site being approached

- eliminate the distraction (from primary driving tasks) of having the motorist manually locate and tune the receiver to the HAR frequency

- operate on a set of frequencies available nationwide, thus eliminating the co-channel AM station problem which now disallows HAR use in certain areas

- use dedicated receiver or adapter, thus eliminating the problem that not all radios can receive HAR messages.

The AHAR development program, initiated in 1980, comprised three phases:

1. review, analysis and design
2. engineering model development
3. prototype development and demonstration.

The AHAR system prototype was developed to the stage where it is technically proven. It can utilize either burst transmission of digitally encoded synthesized speech or analog audio message transmission. It avoids the need for roadside signing and manual tuning by using a subsidiary FM receiver which automatically mutes the car radio and tunes to the AHAR frequency (45.80 MHz) on entering the coverage area of the AHAR transmitter (if a message is being transmitted). The radio is returned to its normal state after the message has been received and repeated twice. However, the transition from HAR to AHAR has yet to be made, primarily because of institutional barriers.

d) Autofahrer Rundfunk Information

Outside the U.S. there are other traffic information broadcasting systems which are worth considering. One of these is the West German system known as ARI (Autofahrer Rundfunk Information), developed by Blaupunkt. ARI is widely used in Germany and parts of Austria, Switzerland and Luxembourg.

ARI requires vehicles to be fitted with a specialized receiver. In its simplest form, the ARI receiver detects a sub-carrier amplitude-modulated with an identifying tone and lights an indicator when the driver tunes to an ARI station. A slightly more complex decoder also allows the driver to mute his radio, avoiding the need to listen to the rest of the broadcast by the ARI station. The volume is then restored to a preset level on detecting the special modulation associated with a traffic message. In West Germany, around 60% of car radio receivers can currently operate with ARI, while 80% of new receivers entering the market have ARI capability.

ARI has been tried in the U.S. This version, known as ARI-2, requires the driver to pre-tune to the appropriate station. This system has been implemented in several states including New York and California. However, it has yet to gain widespread acceptance with traffic agencies or motorists.

The sources of traffic information for ARI are made up mostly of observations by police and highway agencies. The information flow process necessarily involves detection of a major change in traffic conditions and its cause; transmission to a radio station; and broadcasting to the motorist. This inevitably involves a significant delay, which can result in the information being out-of-date by the time it is received. Unnecessary congestion may therefore build up, which might have been avoided if the motorists had been given more immediate access to the information.

e) ARI with Actual Measurement

In an attempt to reduce this delay, an enhanced version of ARI has recently been developed called ARIAM, which translates to "ARI with Actual Measurement." The objective of ARIAM is to automate the process of detecting changes in traffic conditions, disseminating that information to the public using the established ARI network.

ARIAM uses automatic incident detection equipment as the main basis for detecting changes in traffic conditions. Data from incident detection loops installed in the pavement are fed back to an existing traffic control centre, where algorithms are used to analyze traffic conditions. When these algorithms identify conditions sufficiently serious to warrant action, information is sent to the radio stations for broadcasting on the ARI network. Initial tests of the system have shown that information about road and traffic conditions can be made available to the traffic control centre and the motorist around 10-15 minutes earlier than a system relying on non-automated information collection.

ARIAM was initially tested in a pilot scheme in the Rhine-Main area of West Germany. An operational application of ARIAM has now been developed in the control centre of the Autobahn Administration at Frankfurt. If this application proves its reliability, ARIAM may be applied nationwide.

f) Radio Data System

Another traffic information broadcasting system which is being implemented at present in Europe is the Radio Data System (RDS) Traffic Message Channel (TMC). RDS is a facility, defined by European Broadcasting Union (EBU) specification, that provides for the transmission of a silent data channel on existing FM radio stations. Its primary purpose is to identify radio broadcasters and allow self-tuning receivers, capable of automatically selecting the strongest signal carrying any particular program. However, many secondary and additional features have been proposed, including digitally-encoded traffic information messages carried on the TMC.

TMC will provide continuous information to motorists using digitally-encoded silent messages which can trigger a speech synthesizer and display in specially adapted radio receivers. The messages will be language-independent, in that they can be decoded into the language of the user's choice. Incoming messages are stored in receiver memory and can be selected by the user according to region or road number.

RDS has been under development within EBU since 1974. It aims to provide a unified standard to achieve automated tuning, station identification and other mobile data. The system is optimized for mobile reception, so that it is suitable for car radios and portable receivers. Compatibility with existing systems such as ARI has also been considered in developing RDS standards. The specifications were finalized in 1983, after coordination by the EBU with radio receiver manufacturers confirmed that the objectives had been achieved. The standardization efforts of EBU have also led to an agreement being reached on RDS within the CCIR; and Recommendation 643, which covers the main characteristics of the system, was adopted at the Plenary Assembly of the CCIR at Dubrovnik in May 1986. This decision established RDS as a world standard. (For RDS structure and content, see Exhibits 23 and 24)

RDS is now being implemented in several European countries including U.K., the Netherlands, France, Germany and Ireland. In Britain, the BBC has used RDS from 1988 to implement an ARI-type system with automatic re-tuning of car radios to traffic messages. Almost all other Western European countries also have plans to introduce the system in the near future. In a test, currently being carried out in the Netherlands, traffic messages are being encoded on RDS (for typical message categories, see Exhibit 25). Pilot tests are also in progress in Paris-Rennes corridor in France, and in Rhine-Rhone corridor linking several countries of the European Community.
In Europe, the manufacturers of RDS receivers are:

EXHIBIT 23

STRUCTURE OF RDS SEQUENCES

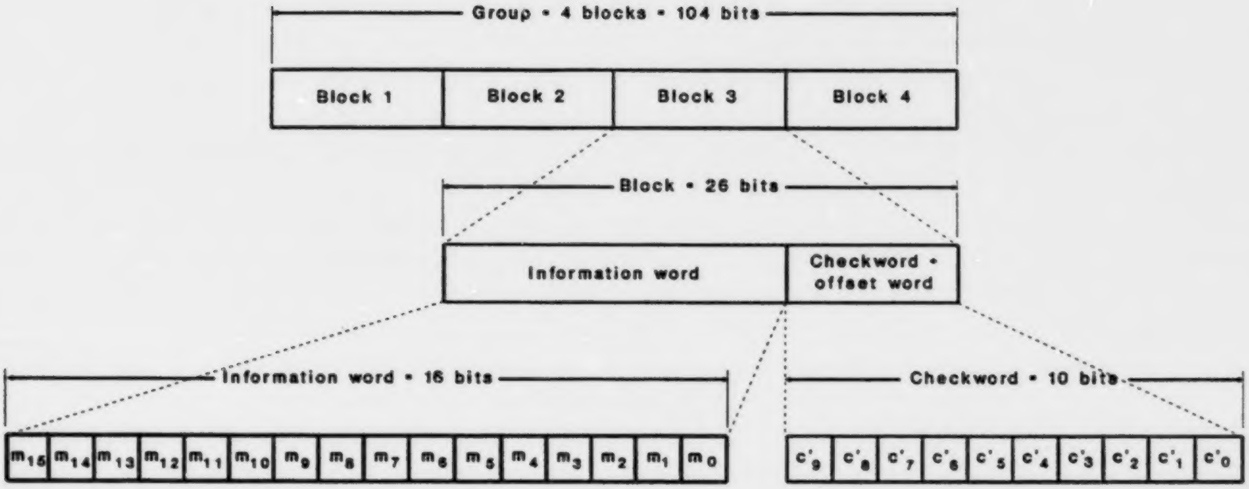
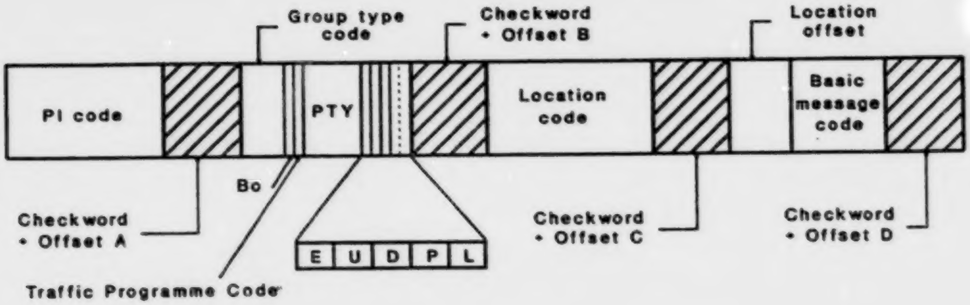

Group = 4 blocks = 104 bits
Block 1
Block 2
Block 3
Block 4
Block = 26 bits
Information word
Checkword + offset word
Information word = 16 bits
Checkword = 10 bits
m_{15} m_{14} m_{13} m_{12} m_{11} m_{10} m_9 m_8 m_7 m_6 m_5 m_4 m_3 m_2 m_1 m_0
c'_9 c'_8 c'_7 c'_6 c'_5 c'_4 c'_3 c'_2 c'_1 c'_0

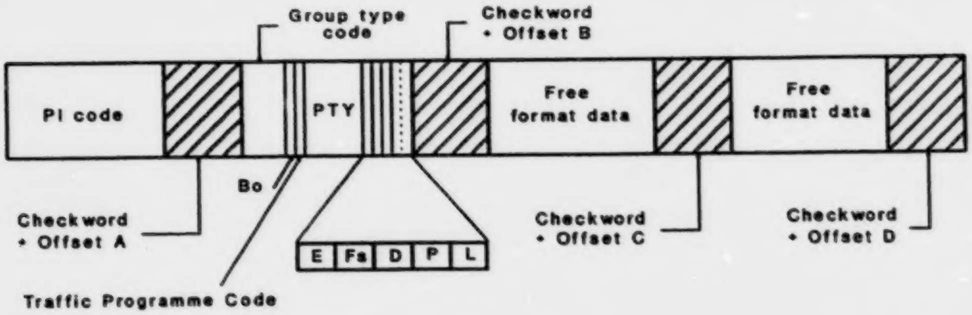
EXHIBIT 24

PROPOSED RDS TYPE 8 GROUP CONTENT

First Sequence


Group type code
Checkword + Offset B
Location offset
PI code
PTY
Location code
Basic message code
Bo
Checkword + Offset A
E
U
D
P
L
Checkword + Offset C
Checkword + Offset D
Traffic Programme Code

Subsequent Sequence


Group type code
Checkword + Offset B
PI code
PTY
Free format data
Free format data
Bo
Checkword + Offset A
E
Fs
D
P
L
Checkword + Offset C
Checkword + Offset D
Traffic Programme Code

Notes :

E = extension bit
Fs= first sequence bit
D = diversion bit
P = persistance bit
L = extended location set
U = - undefined bit
  - or first sequence bit
PI = programme identification code
PTY = programme type code
TP = traffic programme code

EXHIBIT 25

TYPICAL MESSAGE CATEGORIES AT OPERATOR TERMINAL

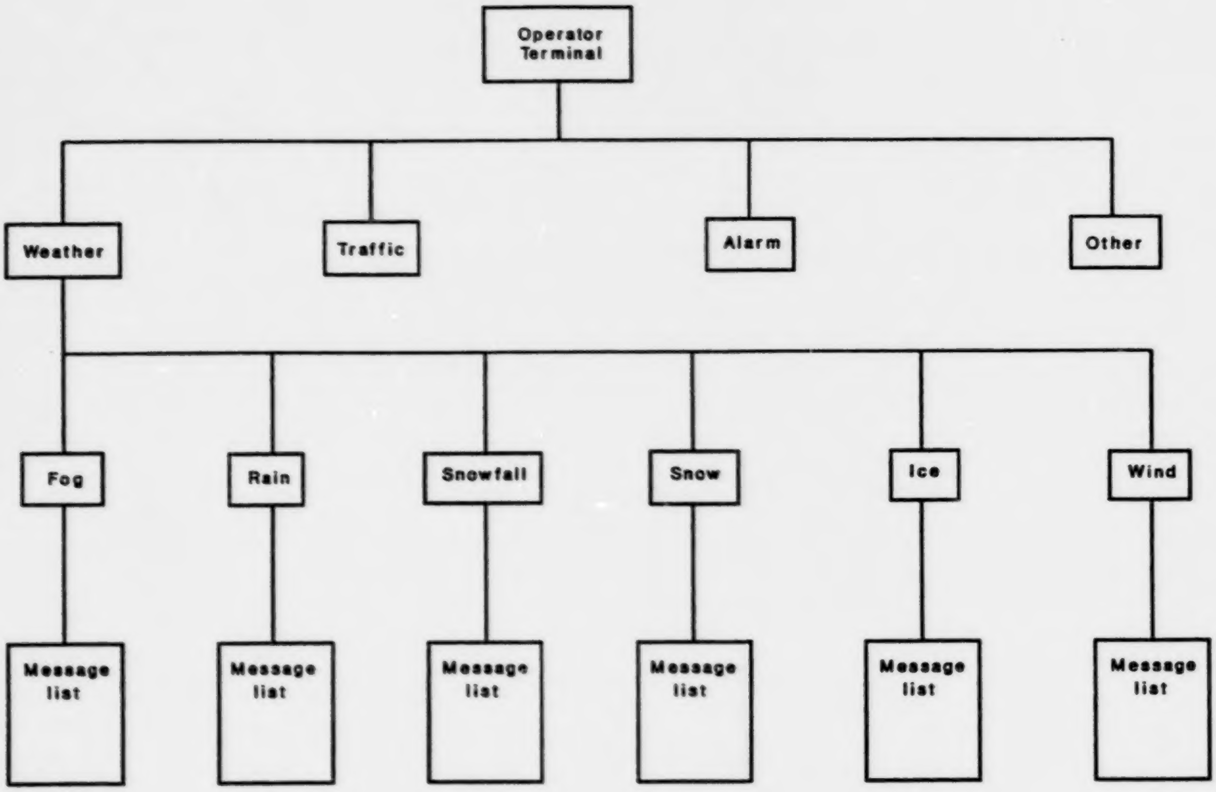
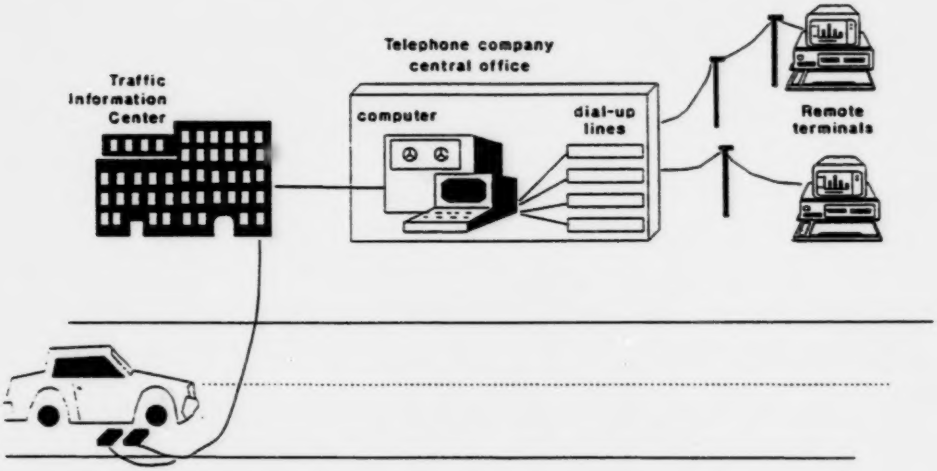

Operator Terminal
Weather
Traffic
Alarm
Other
Fog
Rain
Snowfall
Snow
Ice
Wind
Message list
Message list
Message list
Message list
Message list
Message list

EXHIBIT 26

TRIP PLANNING SERVICES

System Diagram


Telephone company central office
Traffic Information Center
computer
dial-up lines
Remote terminals

- RE Instrument AS		Denmark
- Teli Scandinavian AB	Alvsjo	Sweden
- Philips Bedrijven B.V.	Eindhoven	The Netherlands
- VG Electronics	East Sussex	United Kingdom
- AEG Olympia	Berlin	West Germany
- Robert Bosch GmbH	Hildesheim	West Germany

Studies are also being undertaken in countries outside Europe to investigate the possibilities of implementing RDS. These include Canada and Hong Kong. The RDS concept has been presented to a National Broadcasting Convention in the U.S., where it generated some interest. RDS-TMC has also attracted significant interest among U.S. transportation authorities.

2.3.2 Trip Planning Services

a) Introduction

Electronic route planning and information systems are being developed which allow real-time pre-trip data to be obtained by motorists. These systems link minimum path computer algorithms to highway network databases. Minimum paths can be determined in terms of journey time distance or cost. Users access the route planning computer over a phone line and see their route displayed or printed out. Several system developments are described briefly in the following. (A system diagram is shown in Exhibit 26.)

b) TELETEL

In France, there is a well-developed videotex system called TELETEL, which comprises some 10 000 different interactive services. TELETEL was introduced in 1982 and is now being used by 4.5 million people (1 M installed terminals). France Telecom is acknowledged to have pursued the only successful mass market strategy with videotex services – by giving away three million Minitel terminals free of charge (in order to get past critical mass). Recently there has been a shift of emphasis toward business users, who pay higher rates; more sophisticated terminals are being produced (and charged for).

TELETEL includes a route planning service called ROUTE. Its database contains information on the highway network, together with current information on highway maintenance and construction activities, road conditions and weather.

Other European efforts have not yet lived up to their promise. West Germany's Bildschirmtext (based on CEPT three standard), launched in 1983, has had low take-up: 3000 information providers and 200 000 subscribers are being claimed by Deutsche Bundespost. British Telecom, despite of having invented videotex, has had even less success with its Prestel (95 000 terminals, with 55% business users particularly from the travel industry). However, a system similar to France's ROUTE, called ROUTEFINDER, has been developed by the U.K. Transport and Road Research Laboratory (TRRL).

In the U.S. and Canada there has been a revival of interest in business oriented videotex lately. Southwestern Bell Telephone is running a voice and data gateway trial in Houston (using GPT Data Systems/US Videotel ports). Bell Canada has just completed successful trial of its Alex system in Montreal, and has announced – for 30 April 90 – the availability in Toronto. (CRTC had previously denied applications to offer electronic directory services.) National Telematic Network NTN has unveiled its product (a Canadian Minitel) to compete with Bell's Alex.

While Alex has some travel related services among its 325 providers, it doesn't contain, as of yet, any interactive travel route/weather information for commuting or intercity travel. The rates for Alex 2/3/4 category services are: $7.20/h, $18.00/h and $27.00/h; the first minute of access is free. Renting the terminal costs $7.95/month.

c) ATIS

At a pan-European level, there is a developing system known as ATIS which aims to provide pre-trip information on traffic conditions and other aspects important to tourists. ATIS is based around the European Road Information Centre (ERIC), which is coordinated by the AIT (Alliance Internationale de Tourisme) in Geneva, Switzerland. Important traffic information is reported by the police and motoring organizations in each of the 12 European countries to the centre. Here it is processed and the resulting information is sent back to each country for dissemination.

d) Computrip

In Canada, a system called Computrip has been developed. This provides the motorist with a print-out of a requested route, together with a summary of total distance, the driving time and projected gasoline charges. The driver can choose the shortest or most scenic route between two points, and can also have the location of hotels, car rental agencies and service stations shown on the printout. Computrip can be easily set-up in tourist information centres, hotels or freeway service areas. (Queen's University's Q-Route in-vehicle guidance system uses a computer and cellular phone to map out the quickest route to destination.)

2.3.3 Entertainment/Communication Systems

a) Sound Systems

Entertainment systems have also become quite sophisticated and many microcomputer controlled car radios offer precise digital tuning as well as seek, scan and station memory features. Chrysler's Acustar Division is developing an all Digital Radio using Digital Signal Processing (DSP).

Entertainment sub-systems deserve comment because they become interactive with voice-synthesized alert messages to the driver and also because radio subcarriers are being used to provide European motorists with traffic information (ARI/Section 2.3.1.d). Many national parks offer AM radio information on 530 and 1610 kHz frequencies. Univ of Michigan and others are investigating RDS using standard radio station subcarrier signals, in some cases special satellites transmitting RDS.

Digital Audio Tape (DAT) is competing with the Compact Disk (CD) for high fidelity audio installations in the automobile market. The compact disks used in CD players, are also capable of storing large amounts of text or pictorial data. Special purpose CD players can be made to recover this data to a CRT and some automotive companies have demonstrated this technique to store map data for navigation systems. (Section 2.4)

b) Two-way Communication Systems

Many vehicles are privately equipped with **two-way radio communications**, including Business/Citizen Band and Amateur Radio (HAM). It is important that all of the electronic equipment aboard the vehicle is able to tolerate the radio frequency energy fields emitted by such installations. This is referred to as "Electro Magnetic Compatibility" (EMC). **Cellular telephones** are replacing the old mobile radio telephones. In a few decades continent-wide two-way communication will be commonplace, using car-to-satellite microwave links.

IBM and Motorola have just announced a U.S.-wide radio network **(ARDIS)** which allows users of hand held computers to tap into central computers from nearly anywhere without a telephone line – by using the companies' combined existing (in-house) radio networks. Motorola has offered a similar service for years in New York, Los Angeles and Chicago. Potential users will include field service personnel, real estate brokers, package delivery workers, police officers and insurance agents. The system is on-line all the time, so there is no need to dial up a computer, unlike in computer/modem/cellular phone systems. **MobiData**, launched in Canada by Motorola and BCE Mobile Communications, offers: access to databases, send/receive messages, place orders, issue bills/reports, monitor stock market prices – without having to find a phone or an electrical outlet. By the end of 1990, service will be available in Toronto, Montreal, Vancouver, Calgary, Edmonton, Ottawa, Quebec City. Subscribers will also have access to every major U.S. city through Motorola's Data Radio Network.

c) Office Systems

In addition to voice communication, teletype and facsimile data can also be obtained (e.g., Tokyo taxis). With this type of communication, a lap-top computer, and a small printer (taxis in Finland), the traveller has a **mobile office**. Personal computers that can be plugged into the automobile's power and 2-way communication system or unplugged to be used as a lap-top may even be offered by the car makers. Portable storage media, such as the 200MB 'Disk Pack' removable hard drive, will allow a mobile office to contain an individualized work environment. In-vehicle information systems will undoubtedly soon incorporate features of the **pocket secretaries** (e.g., Sharp IQ-7000 Electronic Organizer, Psion Organizer II XP, Casio SF-4000 digital diary) and **language translators** (e.g., Hexaglot, with 40 000 words and 50 phrases in English, French, Italian, German, Spanish and Portugese).

In-vehicle versions of **electronic books** will likely soon be available. They have a display screen similar to a lap-top computers and read text or pictorial data from a multi-megabyte memory device. Eventually entire books will be available on a thin plug-in card. With a built-in CRT or LCD display in the car, it would seem logical to provide for compatibility with the electronic book laser cards. Detailed owner's manuals, and maintenance/repair instructions could then be read directly on the car's own CRT. (Ford will supplement its 1991 Explorer owner's manual with a video tape; U.S. DOD is putting technical manuals and hazardous materials systems on CD-ROM). The **Electronic Whole Earth Catalog** is already available on CD-ROM: of the 420MB stored, 360MB are sound files (placed in stacks using Farallon's MacRecorder). **Computerized atlases**, such as De Lorme's World Atlas, PC Globe's PC Globe 3.0, PC Nations and PC USA (available on 5, and 3 inch disks), Grolier's The New Electronic Encyclopedia, and Microsoft's CD-ROM based 'Bookshelf' **reference library** are basically ready for in-car use. Industry references, e.g., 1990 Thomas Register, will soon come out in electronic versions.

The advancements made with a broad range of **geographic information** systems in the past two years will infiltrate to automotive field. One unusual application – Domesday, a video-laser based U.K. mapping system – contains 324 MB of digital data + 60 min of movie film: 150 000 pages of text, 23 000 photos, 270 000 place names. Mobile GIS are appropriate for numerous service sector and business applications, e.g., maintenance of municipal facilities, real estate services, etc.

d) Video Systems

Video entertainment for passengers in the form of backseat TV plus video cassette recorder/player is common in Japanese taxi cabs. These systems are also available on the after-market for recreational vehicle application. Most TV video games can be adapted to these rear seat systems to provide activity for children while travelling. The interactive video disk has also the potential for serious educational training since it allows for a number of alternative video sequences to follow different responses from the viewer.

e) Closing Thoughts

The deluxe passenger car offers much more than basic transportation. In-car comfort, convenience, and entertainment systems already rival those of the home. Coming soon are more of the enhanced safety and performance enhancing systems described above. ABS/Traction Controls, suspension systems and improved steering systems all linked together into an integrated chassis control system will be in communication with the engine control computer and the transmission control computer. An integrated vehicle system will be formed by the interaction of many computer controlled sub-systems that are coordinated by a central unit handling all of the executive functions, but leaving the real-time closed-loop controls to individual sub-systems dedicated to specific functions.

2.4 Vehicle Navigation and Route Guidance Systems

2.4.1 Introduction

Advanced vehicle/highway technologies under development in Europe, Japan and the United States – for applying computer, communication and automation technologies to improve efficiency of traffic flow, roadway capacity, safety, and environmental conditions – include in-vehicle navigation and driver information systems as a major thrust. The development of these systems has already progressed to the stage of large-scale pilot demonstrations in Europe, and to the introduction of early versions with limited capabilities as optional equipment on top-line automobiles in Japan. The first small-scale demonstration is getting underway and a second is being planned in the United States.

Based on current trends, navigation and route guidance systems using dead reckoning with map matching for determining vehicle position will be widely available by the end of the 1990s. These systems may include Navstar GPS receivers for auxiliary position information, and will include one- or two-way communication links with the infrastructure for receiving traffic or route guidance information. The systems can be expected to provide some relief from traffic congestion through dynamic reduction in traffic accidents, if designed with safety considerations in mind.

The *Mobile Information Systems Impact Study* [1] provides a fairly extensive state-of-the-art review on these systems. For ease of reference, a short description of the system characteristics is included here also, followed by an update matrix on the features of the main systems currently available or close to being on the market.

2.4.2 System Characteristics

To be most effective, navigation and driver information systems require in-vehicle equipment, supporting infra-structure, and a two-way communication link connecting the two. The in-vehicle equipment for comprehensive driver information systems of the future is expected to include the following features:

- means for automatically determining vehicle location with sufficient accuracy to identify the road travelled and each intersection approached

- digital maps to identify the location, class, traffic regulations, and address ranges for each road in areas where the vehicle operates; and to provide the locations and descriptions of service stations, garages, parking, public buildings, hotels, restaurants tourist attractions, and other types of commonly used "directory" information

- route guidance software and driver interface means to determine the optimum route and to present real-time route instructions to a specified destination

- mobile communications transceiver for receiving traffic and other variable data (e.g., available parking) for the area being travelled, and for transmitting travel times actually experienced over different road segments to the traffic control centres for augmenting data on local traffic conditions.

Vehicle location is determined by various combinations of dead-reckoning, map-matching, satellite-positioning and proximity-device technologies. Dead reckoning is the process of calculating a vehicle's location by integrating measured increments of distance and direction of travel away from a known initial location. Since distance and heading measurements always have some errors, dead-reckoned vehicle location accuracy gradually decreases until the vehicle location is updated by map matching or by other means.

Map matching is an expert system type process that recognizes a vehicle's location by matching its apparent path with the patterns of digital road maps stored in a computer file (e.g., CD-ROM) – which is also used to generate map displays, route guidance, directory information, etc. For example, each time a vehicle makes a turn of which the location, direction, etc. closely match those of a mapped turn, the vehicle is presumed to be at the mapped location. Dead-reckoning with map matching is used in virtually all state-of-the-art systems.

Satellite positioning systems provide accurate location information when a vehicle's satellite receiver has simultaneous signal reception from three different satellites. However, high-frequency radio signals from satellites not directly overhead are often blocked by buildings in urban areas where driver information systems are most needed. Since dead reckoning is required to fill these gaps, the main use of satellite positioning in driver information systems will be to eliminate occasional situations where dead reckoning with map matching may fail due to extensive travel off of mapped roads, after ferry crossings, etc. the Navstar GPS (Global Positioning System), scheduled to be completed in three years by the United States Department of Defense is the principal satellite system considered for use with driver information systems.

Proximity devices are short-range signal emitters that are strategically located (i.e., at key intersections, etc.); and the very reception of the location-coded signal of a beacon by a passing vehicle provides that vehicle's position. Dead reckoning with map matching is used for navigating between beacons. The proximity beacon's drawback of requiring extensive roadside equipment is partially offset by its usefulness as a communication link for traffic and other localized data (such as in Toronto Transit Commission's AVL application).

Other alternatives for data communication between vehicles and traffic data centres include broadcast sub-carrier, cellular radio and mobile satellite. The broadcast sub-carrier approach, which superimposes inaudible data on the sideband of regular commercial FM radio stations for decoding by an inexpensive attachment (in ordinary radio receivers), is limited to one-way communication. It is called Radio Data System in Europe where it is being tested for communicating traffic alerts (Section 2.3.1). Various adaptations of cellular radio are also being tested in Japan and studied in Europe. The appeal of mobile satellites is presently limited due to their large signal footprints which are ill-suited for communicating traffic data specific to small local areas or corridor segments.

2.4.3 Features and Specifications of Existing Systems

Numerous navigation systems are under development worldwide and many have been shown in concept cars or demonstrated in experimental or prototype stages. However, only very few of the current generation of relatively unsophisticated systems have became available as options that may be ordered as original automotive equipment or purchased for after-market installation.

The features and specifications of major systems actually on the market, or that are about to be introduced or are already included in major demonstration and evaluation programs, are presented in Exhibit 27 for the following:

- Ali-Scout (basis for Berlin and London demonstrations)

- CARIN (Philips system)

- Etak Navigator (regular U.S. market version)

- Etak Travel Pilot (which is the licensed-for-Europe, CD-ROM version of Etak Navigator developed for Bosch-Blaupunkt; and which, for the time being, has superseded EVA within Bosch-Blaupunkt)

- two generic systems (consolidated concept specs)
  - AMTICS
  - RACS

- Toyota Electro Multivision

- Nissan AV System.

The 2-page matrix on the state-of-the-art of (a short-list of) vehicle navigation/route guidance systems updates and complements the information originally provided for those systems, as part of the Mobile Information Systems Impact Study (Exhibit 13, pages 69 to 71 of [1]). The matrix contains several sub-headings (features) that are not yet provided by any of the presented systems; this will help continued follow-up of system modifications, or new systems being introduced to the market.

EXHIBIT 27

VEHICLE NAVIGATION/ROUTE GUIDANCE SYSTEMS

* CURRENT FEATURES *

SYSTEM IDENTIFICATION Name	ALI-SCOUT	CARIN	NAVI-GATOR	TRAVEL PILOT	AMTICS	RACS	ELECTRO MULTIV	MULTI AV SYSTEM
Manufacturer	Siemens	Philips	Etak	Bosch/Bl	Various	Various	Toyota	Nissan
Location	Munich WGermany	Eindhovn Holland	MenloPrk CA, USA	Hildesheim/WG	Japan	Japan	Tokyo Japan	Yokosuka Japan
COMMUNICATION TECHNOLOGY								
self-contained vehicle system		x	x	x			x	x
area broadcasting /1-way					x			
local roadside transmitter/1-way								
mobile radio system /2-way								
local roadside transponder/2-way	x					x		
cellular								
satellite								
DEAD RECKONING TECHNOLOGY								
Odometer	x				x	x	x	
Differential Odometer		x	x	x				x
Magnetic Compass	x	x	x	x	x	x	x	x
Other___				x inclinom.				
OTHER NAVIGATION TECHNOLOGIES								
Map Matching	x	x	x	x	x	x	x	x
Proximity Device___	infrared					microw		
Satellite System___								
Loran-C								
SYSTEM FUNCTIONS								
Location on Map Display					x	x	x	
Distance & Direction to Destination	x		x	x				x
Location & Destination on Map Display			x	x				x
Explicit Route Guidance	x	x				x		
Personal/Bus Communctns - voice, digtzd data, fax,..						o		
- storage-in/display on dmnd								
Driver/Cargo /Vehicle - on-board monitoring								
- control & assistance								
Environment Sensing - weather, etc								
- obstacles detection								
Information Strg&Displ - directories (yellow pgs,..)							x	x
- traffic rules (in r gdnc)								
Data Base Mgt & Word Processing								
Information Recording (black box) & Exception Reporting								
MAP FORMAT								
Hard Copy								
Digitized - matrix encoded								
- vector encoded	x	x	x	x	x	x	x	x
Zoom Capability (no of levels)			9	9	x	x	x	x
Turning map (heading continuously up)			x	x			?	x
MAP/INFORMATION STORAGE								
RAM	x							
Magnetic Tape			x					
Magnetic Disk								
Compact Disk (CD-ROM)		x		x	x	x	x	x
Digital Audio Tape (DAT)								
Other___								

FOOTNOTES (not all features are necessarily recorded)

1) Used in LISB pilot project in West Berlin and in Autoguide demonstration project in London.

2) Early version included a colour CRT map display, which may be available as an option with future systems.

4) Lincensed version of Etak Navigator. Nine scales (=cursor to screen top) = 200m, 400m, 800m, 1.5, 3, 5, 10, 25, 50km.

EXHIBIT 27 (continued)

VEHICLE NAVIGATION/ROUTE GUIDANCE SYSTEMS

* CURRENT FEATURES *

SYSTEM IDENTIFICATION Name	ALI-SCOUT	CARIN	NAVI-GATOR	TRAVEL PILOT	AMTICS	RACS	ELECTRO MULTIV	MULTI AV SYSTEM
Manufacturer	Siemens	Philips	Etak	Bosch/Bl	Various	Various	Toyota	Nissan
DISPLAY TECHNOLOGY								
CRT Type			Vector	Vector	Raster	Raster	Raster	Raster
Colour			No	No	Yes	Yes	Yes	Yes
Screen Size (diag cm)			11	11			15	15
LCD	x	x						
Plasma								
Luminescent								
Printer___								
Character Size & Definition (pixels)								
MultiFunction (TV, vcr, veh diagns,...)					o	o	x	x
AUDIO OUTPUT								
Annunciator (chime, tone, ...)	x							
Voice (recrdd analog, digitized, synthszd)	x	x						
DISPLAY/OUTPUT CONTENT								
System Controlled: constant/hazard driven								
User Selectable Overlays			o					
INPUT & CONTROL								
Keyboard/Keypad		x	x	x	x	x	x	x
Remote Keypad	x							x
Touch Screen							x	
Voice Recognition								
Scanner / Wand / Mouse (tied-in vs. remote)								
Other (floppy disk, mag card,...)								
External - retention & recall								
Input - incorp/message into overlays								
POTENTIAL USE								
Travel Advisory	x	x	x	x	x	x	x	x
Traffic Management	x				x	x		
Fleet Management					x	x		
Mobile Office						x		
Service Directories							x	x
Training & Education								
Entertainment							x	x
Vehicle Control								
Other___								
INSTALLATION								
Position of - stand-alone	x		x	x				
Interface - dash/console/st.wheel/oth		d			d	d	d	d
Modular (some components in trunk, etc)	x	x	x	x	x	x	x	x
Integrated with Entertainment System		x					x	x
Integrated with Other Systems								
Screen Position: locked vs. tilt&swivel	s	L	s	s	L	L	L	L
Removeable - security only								
Components - display to rear seat								
- external operation								
Security Feature (hddn trnsmtr, self-dstrct)								
SYSTEM STATUS								
Proposed								
Experimental								
Prototype		x				x		
Pilot	x				x			
Production (year introduced)			1985	1989			1987	1989
COMMENTS	1	2	3	4	5	6	7	8

5) These specs are typical of approximately 12 versions developed by various manufacturers for testing with the Advanced Mobile Traffic Information and Communication System teleterminals of the National Police Agency.

6) These specs are typical of approximately 12 version developed by various manufacturers for testing with the micro-wave beacon Road/Automobile Communications System (RACS) of the Ministry of Construction.

8) Navigation software supplied by Sumitomo Electric Industries Ltd.

3 HUMAN FACTORS CONSIDERATIONS

3.1 The Driving Task

The task of driving can be divided into three sub-tasks: navigation, manoeuvring, and control. **Navigation** involves planning and following a route. **Manoeuvring** involves avoiding obstacles. Control involves the vehicle handling, that is speed and lane position control. Offering driver support in navigation, manoeuvring and control has the potential to increase safety and efficiency. However, there is also the potential to overload driver with information, thereby increasing his mental workload and decreasing the amount of attention that can be paid to the non-automated portion of the driving task.

Until support systems reach a point where driving is fully automated, it will remain the task of the driver to monitor the environment for hazards. The more attention that must be paid to the support systems, the less attention can be paid to this critical task. For this reason, it is of the utmost importance that the design of support systems is centred on the needs and the limitations of the driver.

Adding a support system will change the driving task in unforeseen ways. Therefore, it is also vital that support system designs receive a full human factors evaluation. This chapter focuses on driver characteristics that need consideration, human factors issues related to various support system types (i.e., automatic fleet monitoring, vehicular monitoring and control, vehicle navigation and route guidance systems, and auxiliary travel support systems). The need for an integrated intelligent system and evaluation issues – both to guide design and to support regulation with respect to support systems – are discussed.

The material presented here is complementary to the discussion on "the human processor," "man-machine interface," and the display/control design guide and preliminary standards material contained in the *Mobile Information Systems Impact Study* [1] (Chapter 3, pages 74 to 98 and Section 6.3.2, pages 164 to 166).

3.2 Driver Characteristics

3.2.1 Introduction

In the design process, the role of the ergonomist or human factors specialist is to consider all aspects of the human component in much the same way as the engineer looks at the capacities and limitations of the mechanical components. What the ergonomist can offer is by no means a complete set of design specifications, but rather a set of ranges within which the designer can be assured the abilities and limitations of the human operator will be accommodated. There are four principal areas in which driver abilities and limitations must be considered: physical, perceptual, cognitive, and motivational (refer also to Exhibits 28, 29). In terms of:

- physical capacities – the design and layout of controls must be such that they can be easily reached and operated by all drivers; here anthropometric data on various population groups must be considered

- perceptual capacities – consideration must be given to such matters as legibility of visual material and clarity of auditory presentations, under various conditions (e.g., where glare or low light is present or where noise levels inside the vehicle are high) and for drivers of different ages and visual/hearing capacities

- cognitive capacities – consideration must be given to information processing rates in different traffic situations for drivers of various levels of experience and of different ages; one must also take into account short term memory capacities, effects of expectation on response (population stereotypes), and decision making in the face of the false alarms and missed signals

- motivational factors – consideration must be given to the fact that drivers have different driving styles; some take more risks than others, driving at the limit of their own or their vehicle's abilities; some are more preoccupied (either by internal thoughts or accessories in the car, or by conversation with passengers) and more inattentive than others.

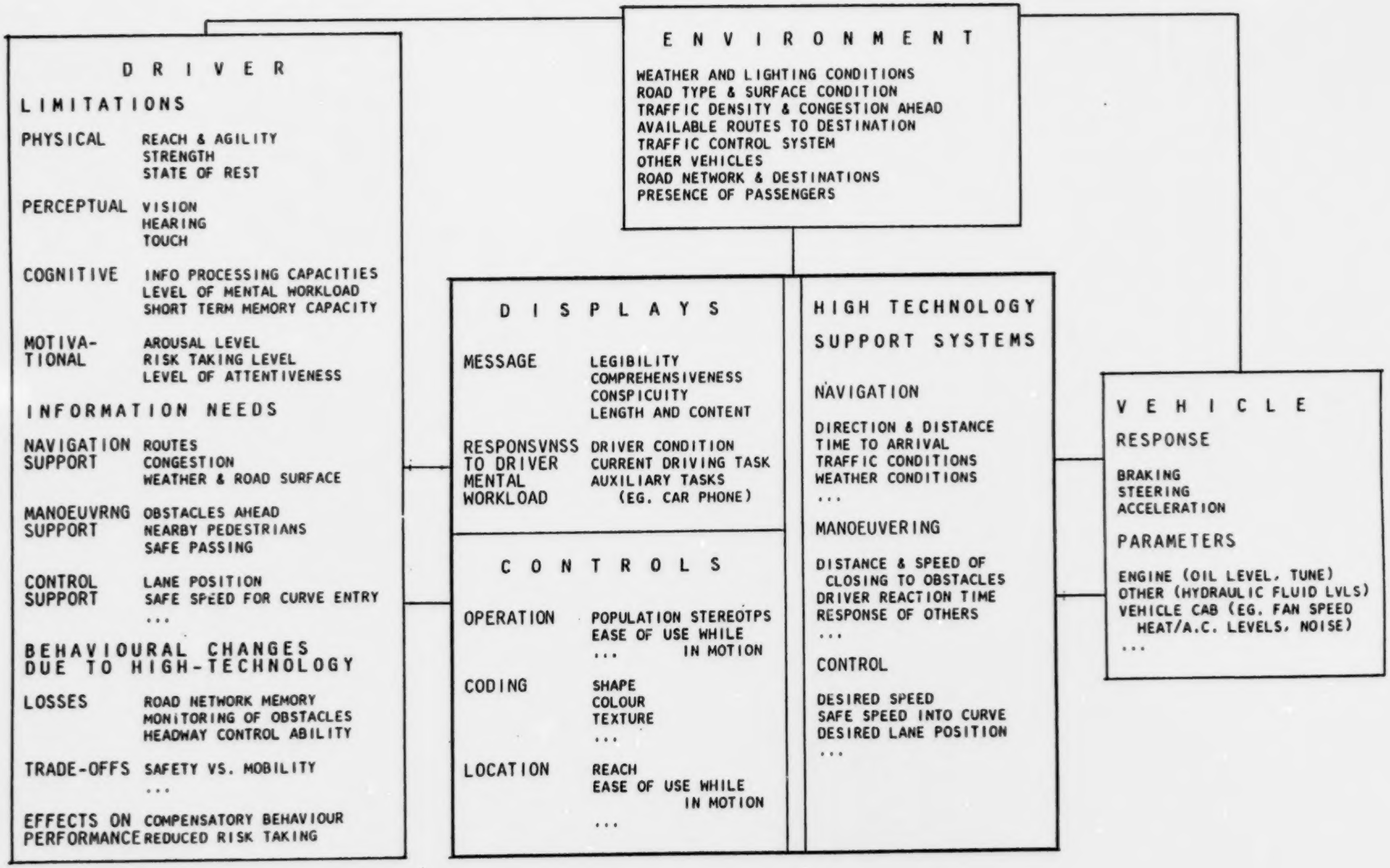
Some of the human factors literature which is relevant to human physical, perceptual and cognitive limitations has been reviewed by Parviainen et al, in Phase I of this project [1]. This chapter focuses on more the global human factors concerns in the design of driver support systems. These are: the mental workload associated with the various support system designs, the manner in which drivers need to be trained to use the new support system, and the factors which will affect how readily drivers accept and use the new technology.

3.2.2 Mental Workload

In the introduction it was noted that the new support systems have the potential for overloading the driver with information. The Phase I report emphasized the fact that humans are limited in their information processing abilities. To reduce information processing demands, preliminary guidelines for design were suggested. However, preliminary guidelines for design are only a first step.

EXHIBIT 28

INFORMATION NEEDS AND HUMAN LIMITATIONS TO BE CONSIDERED IN THE APPLICATION OF HIGH TECHNOLOGY IN VEHICLES



DRIVER

LIMITATIONS

PHYSICAL	REACH & AGILITY STRENGTH STATE OF REST
PERCEPTUAL	VISION HEARING TOUCH
COGNITIVE	INFO PROCESSING CAPACITIES LEVEL OF MENTAL WORKLOAD SHORT TERM MEMORY CAPACITY
MOTIVA-TIONAL	AROUSAL LEVEL RISK TAKING LEVEL LEVEL OF ATTENTIVENESS

INFORMATION NEEDS

NAVIGATION SUPPORT	ROUTES CONGESTION WEATHER & ROAD SURFACE
MANOEUVRNG SUPPORT	OBSTACLES AHEAD NEARBY PEDESTRIANS SAFE PASSING
CONTROL SUPPORT	LANE POSITION SAFE SPEED FOR CURVE ENTRY ...

BEHAVIOURAL CHANGES DUE TO HIGH-TECHNOLOGY

LOSSES	ROAD NETWORK MEMORY MONITORING OF OBSTACLES HEADWAY CONTROL ABILITY
TRADE-OFFS	SAFETY VS. MOBILITY ...
EFFECTS ON PERFORMANCE	COMPENSATORY BEHAVIOUR REDUCED RISK TAKING

ENVIRONMENT

WEATHER AND LIGHTING CONDITIONS
ROAD TYPE & SURFACE CONDITION
TRAFFIC DENSITY & CONGESTION AHEAD
AVAILABLE ROUTES TO DESTINATION
TRAFFIC CONTROL SYSTEM
OTHER VEHICLES
ROAD NETWORK & DESTINATIONS
PRESENCE OF PASSENGERS

DISPLAYS

MESSAGE	LEGIBILITY COMPREHENSIVENESS CONSPICUITY LENGTH AND CONTENT
RESPONSVNSS TO DRIVER MENTAL WORKLOAD	DRIVER CONDITION CURRENT DRIVING TASK AUXILIARY TASKS (EG. CAR PHONE)

CONTROLS

OPERATION	POPULATION STEREOTPS EASE OF USE WHILE IN MOTION ...
CODING	SHAPE COLOUR TEXTURE ...
LOCATION	REACH EASE OF USE WHILE IN MOTION ...

HIGH TECHNOLOGY SUPPORT SYSTEMS

NAVIGATION

DIRECTION & DISTANCE
TIME TO ARRIVAL
TRAFFIC CONDITIONS
WEATHER CONDITIONS
...

MANOEUVERING

DISTANCE & SPEED OF CLOSING TO OBSTACLES
DRIVER REACTION TIME
RESPONSE OF OTHERS
...

CONTROL

DESIRED SPEED
SAFE SPEED INTO CURVE
DESIRED LANE POSITION
...

VEHICLE

RESPONSE

BRAKING
STEERING
ACCELERATION

PARAMETERS

ENGINE (OIL LEVEL, TUNE)
OTHER (HYDRAULIC FLUID LVLS)
VEHICLE CAB (EG. FAN SPEED HEAT/A.C. LEVELS, NOISE)
...

EXHIBIT 29

RANGE OF DRIVER, VEHICLE AND ENVIRONMENT CHARACTERISTICS TO BE CONSIDERED IN DESIGN, TESTING AND OPERATION

DRIVER	CHARACTERISTIC	+ +	- -
PHYSICAL	PHYSICAL STATE	rested	fatigued
	PHYSICAL CONDN	ok	in pain
	ALTERED STATE	sober	impaired
	MOVEMENTS	agile	restricted
	REACH	far	short
	STRENGTH	strong	weak
	HANDED	right	left
PERCEPTUAL	VISION	20/20	20/40
	CONTRAST SENSTVTY	excellent	poor
	HEARING	excellent	poor
	TOUCH	sensitive	insensitive
COGNITIVE	INFO PROCESSING	high capacity	low capacity
	REACTIONS	fast	slow
	SHORT TERM MEMORY	excellent	poor
MOTIVATIONAL	AROUSAL	moderate	high / low
	RISK-TAKING	low	high
	ATTENTIVENESS	alert	inattentive
	FOCUS	driving tasks	other
OTHER	SITUATION	no hurry	big hurry
	DRIVING EXPERNCE	long	short
	DRIVING KNOWLEDGE	great	limited
	LITERACY	literate	illiterate
	LANGUAGE COMPRH	yes	no

EXHIBIT 29 (continued)

	FACTOR	+ +	- -
PASSENGRS	BEHAVIOUR	quiet	unruly & noisy
	CONFLICT	none	intense
VEHICLE	HANDLING	good	poor
	DRIVER FIT	comfortable	uncomfortable
	SEAT BELTS	on	off
	MECHANICAL CONDN	excellent	poor
	MAINT CONDN	clean	dirty
TRAFFIC	DENSITY	free flow	stop-and-go
	SPEEDS	40-60 km/h	120-140 km/h
	MIX	cars only	trucks & motorbikes/bikes/peds
	CONTROL DEVCS	operating & visible	malfunction & misaligned & dirty
	SIGNS	easy to locate & read	difficult to locate & read
	OTHER VEHS	equipped with support	not equipped with support
	OTHER DRIVERS	driving safely	driving dangerously
ROAD	ALIGNMENT & GRADIENT	straight & flat	tight curve & descending
	VIEW	wide open	restricted
	CONDITION	smooth	rough & hazardous
	SURFACE	clear & dry	iced
	LOCATION	familiar	unfamiliar
	BACKGROUND	noninterfering	cluttered+ glaring
WEATHER	TIME OF DAY	day	night
	VISIBILITY	excellent	none
	WIND	none	strong/side

The new support systems will change driving by automating some tasks and presenting the driver with information he or she did not previously have to help with other tasks. In some cases hands-on control will be replaced by keeping an eye on the performance of the automatic system. In other cases the information processing requirements will increase. In either case the proportion of the time the driver spends monitoring rather than physically controlling the car increases. In other words, the new support systems will affect the level of mental workload involved in driving.

If one wishes to determine the impact of a new device on driver performance it is not sufficient to only measure overt performance, such as lane position variability or headway variability. One must also measure the level of mental effort required to produce that performance. The more mental effort associated with the task of navigating and controlling the car, the less mental capacity there is for monitoring the environment for other traffic, pedestrians, and road surface conditions. If the use of support systems results in a deterioration of performance or an increase in mental workload, then they have failed to live up to their objectives of increasing driver safety and system efficiency.

Mental workload is not only related to task difficulty, but also to effort and to arousal. For a given task – for example, following another vehicle – the mental workload is lower if the driver's criterion for good performance is low and he/she makes little effort to keep his/her headway constant. A novice driver doing exactly the same task as an experienced driver has a higher level of mental workload because he must make more effort to attain the same level of performance. The more difficult a task, the more aroused the driver. Thus, urban driving will be more arousing than rural driving, reflecting a higher level of mental workload. In essence, mental workload depends on the interaction between the driver's task, level of effort, and level of arousal. Performance is best with a moderate level of mental workload. If a task becomes too easy, performance actually deteriorates, similarly if the task is too difficult.

There are essentially four approaches to measuring mental workload. The different approaches reflect the interaction between the factors of task difficulty, effort and arousal. Measures used are as follows:

a) primary task measures: as the task becomes more difficult, performance deteriorates

b) secondary task measures: while performing a primary task the driver also performs a secondary task such as doing mental arithmetic or discriminating audio or visual signals; the more difficult the primary task the poorer the performance on the secondary task

c) physiological measures: as the primary task increases in difficulty, physiological arousal increases

d) subjective measures: as the primary task increases in difficulty, so does the driver's estimate of his/her own workload.

There are advantages and disadvantages associated with the use of the various categories as well as the various measures within each category. The correlations between the different measures are not high, indicating that mental workload has a multi-dimensional character, and that the various contributors to it – namely, arousal, effort, and task difficulty – are not well correlated with each other. Since each measure reflects different aspects of mental workload, it is important that, when it is evaluated, measures from more than one category are taken.

Measures of mental workload will be useful in:

1. distinguishing between the information processing load of different designs of various support systems

2. determining what level of mental load is associated with the various combinations of tasks (driving and auxiliary)

3. determining on-line levels of mental workload so that the information presented to the driver can be adapted to the demands of his current level of driving task difficulty.

During evaluation, the measures suggested above may be used to assess workload levels for various support system designs and various task combinations. However, with an operating system it is obviously not feasible to require drivers to be hooked up to devices that record physiological measures, or require them to perform secondary tasks while driving in order to measure mental workload. Instead an adaptive (intelligent) system will have to infer the level of mental workload from a number of input variables related to driver state (experienced/inexperienced), driver task (e.g., crossing intersection and adjusting radio), driving environment (night, rain, etc.). The level of workload should then affect the way the system presents messages (accompanied by alerting tone, more slowly, after a delay, etc.).

3.2.3 Driver Training on Support Systems

Human factors considerations do not end with the design and installation of a new device in a vehicle. While attention to human factors issues will ensure the device is "user-friendly," drivers will still require some time to learn how to use it, either through "trial and error" or specialized training. While manuals should be provided, the likelihood that they will be read thoroughly and completely understood by all drivers is minimal. Even if the manual has been read, there may be certain features of the system that can only be experienced if the vehicle is in motion.

The risks involved in allowing drivers to "learn on the move" under something other than controlled conditions needs to be seriously considered.[3] Should the alternative of controlled education be adopted, the question arises as to who will be responsible for teaching drivers to use advanced systems. Possible alternatives include car dealerships, driver training schools (special course), equipment suppliers/installers, and the Ministry of Transportation.

Consideration would have to be given to how such education would be regulated and to whom should it apply (new drivers, elderly drivers, all drivers). The trend in past decades has been that as a machine increases in complexity, regulations with respect to training and licensing become more stringent. In the early days of cars and airplanes no licensing was required. If there is a significant learning curve with the introduction of high-technology devices, the government may well wish to require that drivers demonstrate their proficiency before using the devices while driving.

No matter what the mandatory training and proficiency test requirements, the likelihood of careless and inappropriate use of some of the functions must be recognized in the design of system hardware and software. More sophisticated systems should probably incorporate internal training functions – to be available as a driver option; or fully automated ones, which are based on the in-vehicle device monitoring the manner in which it is/has been used by each driver – as well as built-in buffers to protect, based on previous performance, those likely to misuse the device or some of its functions.

3.2.4 Driver Acceptance

If any new technology is to be effective in reaching its goals, it must be accepted and trusted by drivers. The most important issue in determining driver acceptance is system reliability. For example, if an obstacle detection system misses important threats then drivers will neither trust it nor use it. If the navigation system continually gives the driver directions that cannot be followed (such as to turn on to a street that is

---

3) One need only consider the great difficulties people are known to have when learning to use a VCR (in the comfort of their livingrooms), to become concerned about drivers attempting to get familiar with their navigation units (while at 100 km/h in curve on a rainy night). Some estimate that 25-50% of people suffer from techno-angst, and are in no position to "learn on the move."

one-way in the wrong direction) then the driver will not use it. If advice on routes-to-take, received by the in-vehicle unit from central traffic control, leads drivers to roads that are equally or more congested than the original then the advice will be ignored in the future.

A second issue in driver acceptance is the degree to which the system meets the driver's needs. A system that provides support that is inappropriate because it fails to account for driver capacity (e.g., time needed to react to warnings) will end up frustrating the user.

A most important need is that the driver receive information he or she understands. This brings up the issues of language and literacy. Systems need to be able to operate in different languages – and, in Canada, at a minimum this means the two official languages. This will be of great importance in the area of warnings and advice, where safety could be jeopardized by the presentation of lengthy or complex verbal messages in a language poorly understood by the driver.

Where possible, warnings and information displays should incorporate universal visual symbols[4] and auditory signals. This last point is of particular importance given the estimated illiteracy rate in Canada. Research suggests that one out of every 13 Canadians over the age of 15 can be considered to be functionally illiterate [13].

A third issue is how the available information is used. If it is used for automatic policing or incriminating a driver in an accident after-the-fact, many drivers will be reluctant to buy cars with such devices. By the same token, some drivers – confident of their ability and cautionary manner of driving – will want to install the device, particularly if this means a discount on the annual cost of vehicle insurance. Many fleets will insist on the devices, both for their own and contract drivers (as in the case of tachographs).

A fourth issue is that raised by Bainbridge [14] in an article on the ironies of automation. A sense of independence and personal control seems to be important to human operators. To illustrate this point, she cites an example from an automated power plant control system. The operators would put the system on manual control if

---

4) Their number and variety must however be strictly controlled, and their "universality" (i.e., intuitiveness of the design, speed of comprehension, ease of recall) thoroughly tested; a symbol for which the meaning must be checked from a "symbol dictionary" (i.e., it is obvious to only its graphic designer) will increase driver frustration and can be dangerous in complex driving situations.

their managers were not present. Likewise, some drivers may resist automated systems because they derive satisfaction from developing and maintaining their driving skills.

Driver acceptance is critical to the continued use of high technology. Design with regard to human factors considerations will increase the likelihood of driver acceptance of new technology.

3.3 Effect of New Technology on Driver Performance

Depending on the support system, the new technology will impinge on human performance to varying degrees. Support systems, such as fleet monitoring systems, that are designed to collect data unobtrusively are likely to interfere with the driving task the least. On the other hand, support systems, such as navigation systems, which divert the driver's attention away from the manoeuvring and control of the vehicle are likely to interfere the most.

3.3.1 Automatic Fleet Monitoring Systems

If the system is designed for the purposes of fleet management and the data is collected automatically through trip computers and sensors, then it is unlikely to directly influence driver behaviour – except where speeds or idling are recorded (e.g., by a tachometer) and strict company rules exist. However, should the system be designed such that the driver must record data by keying in entries into an on-board computer, then driving behaviour may be affected – especially if entries can be made while the vehicle is in motion.

Designers will need to consider human factors guidelines in the design of interfaces; positioning and layout of input and output devices; and the amount and type of information to be entered and displayed, and the manner of display.

3.3.2 Vehicular Monitoring and Control Systems

Vehicular monitoring and control systems need to be designed so that they maximize safety and minimize additional workload that could detract from the primary task of driving. Such systems will have the ability to alert drivers to potential danger; monitor manner of driving to improve performance; aid decision-making for drivers (particularly novice and elderly drivers); decrease mental workload by aiding the driver or automating aspects of the driving task; and decrease risk-taking in some drivers by warning about a risky manoeuvre (e.g., entering a curve too quickly).

With respect to each of these roles there are a number of issues which should be considered. While systems, such as obstacle detection devices, have the potential of alerting drivers to imminent danger, the reliability of such devices must be very high. This is because a driver can become dependent on the device, and if for some reason the device fails the driver may be less likely to detect the dangerous situation than he would have been without the device.

A related issue which must be considered is the setting of the threshold level for warnings. No device is perfect; some misses and some false alarms will occur. However, if a device is not sensitive enough, there is a possibility that the device will miss important threats and the driver will grow to mistrust it. On the other hand, the device might swamp the driver with so many alarms that a "cry wolf" effect would occur. In addition, the driver's workload would be increased by the need to investigate many false alarms.

High technology systems can monitor driving with the aim of improving driver performance, for example by warning drivers that they are accepting unsafe gaps for passing, or entering a curve at an unsafe speed. There is a very large assumption here, however. That is that drivers will change their performance as a result of such warnings. Drivers who dislike seat belts quite happily ignore displays in conventional cars warning them their belts are not fastened.

Ideally a system that presents information about driver performance should be one that the driver can override, because there will be many drivers who would be unwilling to have an automated "back-seat driver." For these drivers, or for anybody for that matter, the systems might be developed so that they store performance indicators which can then be reviewed at a later date. If the storage device is removeable, this could be done in a calm atmosphere – perhaps on the owner's PC, which could summarize each driver's (last month's) performance and display advice on what measures to take in order to increase safety and reduce vehicle operating and maintenance cost.

With respect to systems that aid drivers in decision-making, these should be developed only after the designers have a thorough understanding of which tasks the drivers need help with and what manner that help should be provided in. This understanding can be gained from a detailed analysis of the tasks for which the design aims to support the driver. Such a task analysis involves a description of the sequence and actions required to carry out a task. These actions are both physical (turning the steering wheel, checking in the rear view mirror) as well as mental (estimating the speed of the oncoming vehicle).

Task analysis also involves determining all the inputs and outputs required by the driver to perform the task. For example, a very difficult task is that of assessing the speed of closing with another vehicle. There are a number of cues which the driver might use but research has established that the one used is the changing angle subtended at the eye by the width of the vehicle in front. A support system which is designed based on a thorough understanding of the driver's task is more likely to be effective than one based on a superficial appraisal of that task.

A concern in this area is the current lack of understanding as to how advanced decision aid systems influence independent problem solving and the attaining of true skill. For example, if a novice driver comes to rely on the system to warn him that he is following too close, will he recognize a dangerous situation in sufficient time to take appropriate action if the system should for some reason fail?

3.3.3 Travel Support Systems

The impetus behind auxiliary support systems, such as cellular telephones and in-vehicle fax machines, is to allow drivers to use some of their available spare capacity to carry out non-driving tasks. Given that such devices will attract the driver's attention away from the primary task of driving, the effects of using such devices on driving performance need to be evaluated.

While users of car telephones, for example, may be convinced that they are paying adequate attention to the driving task, the many anecdotal stories of such drivers wandering in the lane while on the telephone suggest drivers may not always be capable of judging how much spare capacity they have. Obviously manufacturers are aware of this problem because they protect themselves by instructing drivers that such devices are not to be used while the car is in motion. However, such statements ignore the reality that the whole attraction of such devices is to be able to save time by doing two things at once: driving and working.

Despite the risks involved, such systems are likely to have wider consumer appeal than would a "safety" oriented system such as an automatic monitoring system. Thus, there is an obvious need for an integrated system that will warn drivers and override such auxiliary functions in dangerous situations (sufficiently prior to each situation).

3.3.4 Vehicle Navigation and Route Guidance Systems

One can argue that guidance through unfamiliar territory will be of benefit to the driver in that an electronic map system will reduce the need for awkward paper maps. However, such systems have the potential to increase information processing load and to increase visual/auditory distractions (e.g., glare and flicker from CRT screen), thereby distracting the driver from the driving task.

With any display system, the designer must try to optimize the availability and accessibility of the information. The information should be available when the driver needs it, and in a format that the driver feels comfortable with. Research has shown that some drivers will respond faster to verbal instructions (be they written or oral), while other drivers respond better to graphic or pictorial displays [15]. Such research suggests that navigational systems need to be flexible enough to accommodate the driver's display preference.

In the area of graphic displays, research is needed to determine the optimum level of detail and the type of layout (bar graph, map, etc.) that will maximize efficiency and safety. For verbal directions (auditory or written), length and content of the messages as well as the nature of directions presented (right/left vs. north/south) need to be considered.

Another concern regarding automated route guidance systems is the effect they may have on a driver's ability to learn to navigate through unfamiliar territory. Little is known about how prolonged use of such systems may affect a driver's ability to navigate without a navigation system.

3.4 Need for an Integrated Intelligent System

With currently available technology a driver can be using a navigation system, talking on a cellular phone and checking on his moment-to-moment gas economy. There is nothing to prevent a driver from overloading himself and potentially compromising safety. Current support systems do not select or integrate information according to the demands of the driving task or according to the state of the driver. For this reason, there is a need for an integrated intelligent system which can prioritize warnings and override auxiliary functions if necessary.

An intelligent system should manage the display of incoming information according to the current driving situation (inside and outside the car) and according to current driver state (level of experience, level of alertness) so as to maximize safety. To do this, the integrated system must have an "expert system" at its core which incorporates expert knowledge about driving and drivers in general and knowledge about the particular vehicle being driven and the particular driver.

With respect to the driving task, the expert system must "know" under which circumstances manoeuvring and control information should take precedence over navigation and auxiliary information. For example, an intelligent system will know that if new information about an obstacle crossing the road path is available at the same moment as information on changed weather conditions, it is the former information that must be given priority. The expert system should also "know" when the presentation of incoming information should be delayed so that the driver is not overloaded while, for example, negotiating an intersection.

With respect to driver capabilities, the expert system should know that when a car is being followed, the low end of driver reaction time is such that the driver could need as much as 1.5 seconds to initiate braking if that car were to slow down. In addition, the expert system should know something of the car's capabilities, for example in terms of maximum deceleration. This information – if kept up-to-date by the system through continuous/periodic monitoring (i.e., to notice when brakes deteriorate, etc.) – together with information on each driver's response times will allow the system to calculate safe headways for various vehicle speeds and warn each driver accordingly.

The expert system should also be capable of assessing to some degree, the state of alertness and experience of the driver. In a situation where a driver has not made any movement of the steering wheel for 10 seconds, and the car is in motion, the system should detect that the driver is not alert and sound a loud warning. If the driver was still unresponsive the system might set off the hazard lights and horn to warn other drivers, and gradually bring the vehicle to a stop. With respect to driver experience, an expert system, informed via a "smart card" that the driver is a novice, might, for example, prevent a navigation system from giving the driver non-critical information while the car is in motion. Since the capacity and state of alertness of a particular driver changes over time, the expert system must be capable of being automatically updated, with permanent and temporary changes.

Ideally, an intelligent system would integrate the information from the various support systems in such a way that by taking the driver's current task and state (alertness, experience) into account, the information is relevant to that particular driver's momentary requirements. Some guidelines for the ideal intelligent system are given in the following:

1. Different drivers will bring to the task different capacities and different a priori knowledge; the design should allow for different degrees of experience and familiarity (just as word processing packages cater to novices and experienced users).

2. The information should be presented in a form that is meaningful and quickly understood by the driver (issues of literacy and language need to be taken into account); it is particularly important to determine whether or not symbols, abbreviations and verbal material are clearly understood.

3. The information should be presented at a rate with which the driver can cope.

4. The information should be adequate to allow the driver to successfully carry out the task for which support is being provided.

5. The short-term memory capacity of the driver should not be exceeded.

6. The system should attract the driver's attention when a critical message is being presented.

7. The presentation of the information should be sensitive to the mental load and level of arousal of the driver.

8. Consideration should be given to the driver's reaction time to unexpected situations so that warnings can be given in time to allow the driver to avoid accidents.

9. The threshold for warning systems should not be set so low that the driver's workload in checking out false alarms increases to a point where safety is compromised, nor so high that valid threats are missed.

10. When a critical message is presented, the system should be able to attract the driver's attention under all traffic conditions.

11. If a variety of warning signals are given, the driver should be able to easily distinguish between them.

12. The support system should be sensitive to the level of driver alertness so that warnings become automatic actions if the driver is very drowsy.

To determine whether or not these guidelines have been met, expert knowledge of human limitations and abilities is required.

It is perhaps appropriate to comment here on the current realities of **"expert systems."** In the area of artificial intelligence, the premise behind expert systems is that the knowledge of an expert or experts in a particular area and for a particular task can be incorporated into a computerized decision-making system. The system should then be able to make decisions in that specific domain that are as good as, if not better than, those made by the human expert. To date, there are very few true expert systems. Those decision-aiding systems that have experienced any success have been for tasks that are bound by a very narrow and specific knowledge domain (e.g., diagnostic tools for very specific medical conditions).

The following is a quote from a recent review on expert systems: "Expert systems have no ability to develop new solutions to problems. What they do is match solutions to conditions coded into rules and suggest a canned solution that matches the situation. In effect, expert systems act as automated reference manuals, and any problems that cannot be solved "by the book" are out of bounds."

[Source: What Engineers Need to Know About Artificial Intelligence
W A Taylor; Cambridge, Mass: The MIT Press, 1988]

While there are general problem solving programs available (e.g., SOAR/by Newell, 1988), the human brain far outstrips them in terms of the speed of decision-making and the complexity of inputs which can be handled. Such programs are not at a point where they could compose the core of an on-line expert system. Apart from the limitations of artificial intelligence, the current status of knowledge concerning the driving task in its traditional form or as it changes with use of a support system is by no means complete. Therefore, any integrating system that could be created in the near future is likely to have limited power.

3.5 Evaluation

To ensure the new high technology systems meet their aims of making driving more efficient and safer, evaluation is required. Gaines and Moray [16] describe in detail how a human factors evaluation of a computer-based system might be carried out. They suggest five levels of evaluation:

1. Ergonomic level – wherein the control design and the display layout are checked with respect to ergonomic standards; here aspects such as size of lettering, reach, control shape and so on are considered

2. Operator performance level – where consideration is given to the performance a driver can achieve with the support system, e.g., does the system support rapid responses, correct choices of action and efficient distribution of attention of the part of the driver

3. System level – whereby the capabilities of the system to meet design requirements is considered, e.g.:
   - does the navigation system determine the vehicle's position with acceptable accuracy
   - is the obstacle detection system sensitive enough to detect all important threats

- how well can speed and lane position be controlled in high-technology equipped cars compared to conventional cars.

4. Tactical level – at which consideration is given to the ability of the car/driver system to carry out tactical plans; here the details of the performance are less of an interest than whether or not the task is successfully completed; here one could examine whether or not, with a high-technology equipped car, drivers were able to navigate from A to B faster and with fewer errors, drivers were better able to avoid obstacles and maintain safe following distances, and so on

5. Strategic level – at which consideration is given to whether or not the system achieves its overall aims of allowing the vehicle to be operated more safely and efficiently.

Evaluation is of particular importance when the product being developed will change the operator's task in unforeseen ways. Driver support systems will decrease the driver work load in some areas and increase it in others. The human factors evaluation will help to determine the effects such systems will have on workload and performance, and those design considerations that will counter any negative effects. At a minimum, performance with driver support should be as efficient and as safe as performance without.

In evaluation, testing and operation, one must consider the wide variation in driver, vehicle and environmental characteristics under which each of the different functions of in-vehicle units may be put to use. Drivers vary a great deal in their physical, perceptual, cognitive and motivational characteristics:

- some are right handed – some left handed

- some have excellent contrast sensitivity – some, particularly older drivers, have very poor sensitivity

- some can take in large chunks of information quickly – others, because of inherent limitations, lack of experience or lack of training, can not process nearly as much information

- some drivers take many risks due to ignorance of the consequences, thrill-seeking personality, or being temporarily under duress – others drive more slowly, further behind other cars and are generally more cautious.

Vehicles vary in their handling and braking characteristics, and in their mechanical condition over their life spans. An appropriate warning interval, where both are travelling at the same speed, for a sports car will be quite different than for a tractor-trailer. Traffic conditions vary, as do road and weather conditions. In short there is a wide range of driver/vehicle/road/environment system characteristics to be considered.

One must not only consider what the capabilities and limitations of an "average driver" are – in itself a complex thing to define – but also realize that however a "design driver" is finally specified, he/she can be in significantly different condition to safely operate a vehicle (say nothing about operating the different device functions) depending on the stress he/she is under, on familiarity with the area, etc. A range of conditions for the primary variables that might be used to describe driver, vehicle and environmental conditions are presented in Exhibit 29.

In one extreme, if trying to design for ultimate safety, one would need to recreate the conditions presented by the right-hand column – and allow only that very limited use (if any) of the device functions that does not degrade road safety at all. In the other extreme, assuming the absolutely perfect circumstances in every respect, one would design for the conditions presented by the left-hand column of the range. Obviously neither selection is realistic, and the practical combination of circumstances – that ought to be used in the design and development – lies somewhere in between. What is critical, when difficult research choices need to be made, is that one falls on the side of safety rather than on unwarranted optimism (i.e., about drivers compensating for design flaws by being sensibly cautious under all circumstances).

Many new products are evaluated by the general public on an ad hoc basis after they are marketed, rather than by the manufacturers before they are sold. In the case of driver support systems, such a strategy might well result in consumer rejection because of perceived lack of safety or at worst, lawsuits because of unsafe design leading to accidents. An evaluation carried out in this manner is, in the end, far more costly than an evaluation that takes place during development. Where the consequences are reduced road safety – an increase in property damage, injury and death – leaving the evaluation and selection "to the market place" is a socially irresponsible strategy.

3.6 Conclusions

High technology has the potential for increasing driving efficiency and safety. However it also has the potential for presenting drivers with an avalanche of information. Drivers who are overloaded in this way can end up in serious accidents. The application of human engineering to both design and evaluation will ensure that high technology meets its goals.

Though manufacturers have the responsibility of applying human factors engineering in the design and evaluation phases, it is also incumbent upon governments to apply human factors considerations in the regulation of the new technology. Individual support systems may be well-designed, but their concurrent use may be dangerous.

Government supported research is required to ensure that cars with one or more support systems do not endanger their owners or other drivers.

4 MARKET PERSPECTIVES

4.1 Automatic Fleet Monitoring Systems

4.1.1 Introduction

A summary of current market availability of AVI, WIM, AVL and IPS type devices and systems is presented in Exhibits 7, 8a-8d, 9a-9b, and 10.

4.1.2 Heavy Vehicle Monitoring and Management Systems

Heavy vehicle monitoring and management systems are considered to comprise the following (automatic) technologies:

- vehicle identification
- weigh-in-motion
- vehicle classification
- vehicle location.

The potential market for systems including all or some of these functional capabilities are summarized in Exhibit 30. The key markets are briefly discussed in the following.

Provincial highway agencies need statistical data on truck movements and weights for a variety of purposes. Vehicle counts by type and estimates of axle weights are required. Provinces could deploy WIM/AVC equipment directly in highway travel lanes to obtain this information. Statistical sampling rather than continuous data collection would be sufficient.

Provincial and municipal police and other enforcement agencies require vehicle I.D. data and exact measurements of gross vehicle weights and axle weights. This could be accomplished by replacing current static weight equipment by WIM and AVC equipment, and by installing additional WIM/AVC equipment, at weigh stations and ports of entry, for either enforcement or screening purposes (depending on equipment accuracy).

AVI equipment modified, with the use of personal I.D. cars, to identify and transmit information on drivers would allow monitoring of new hours-worked and operator licence regulations. By connecting the AVI communication system to an onboard computer – which keeps a full electronic log on driving/rest periods, hazardous cargo carried etc. – would further automate the monitoring/enforcement process in case the vehicle (or driver) is called in for an inspection.

EXHIBIT 30

POTENTIAL USERS AND APPLICATION OF HEAVY VEHICLE MONITORING INFORMATION

PUBLIC SECTOR

STATE AND REGIONAL AGENCIES
- Highway Agency
  - highway and facilities planning
  - pavement and bridge design
  - transportation policy & cost allocation
- Motor Vehicle Agency
  - vehicle registration
  - trip permit administration
- Police
  - weight enforcement
  - safety, size, speed and haz materials enforcement
  - registration, permit and license enforcement
- Port Authority
  - terminal management
  - security
- Public Utilities Commission
  - gross receipts or usage tax administration
  - operating authority administration
- Revenue Agency
  - fuel tax administration
- Toll Road Authority
  - toll collection
  - weight, size, and speed enforcement
  - planning and design

FEDERAL AGENCIES
- DOD/Military Traffic and Materials Command (MTMC)
  - hazardous materials monitoring
- DOT/FHWA
  - transportation planning and policy analysis
  - highway cost and revenue allocation
  - regulation (including hazardous materials)
  - design standards
- DOT/Research and Special Projects Adm
  - hazardous materials monitoring
- Federal Bureau of Investigation
  - stolen vehicle and goods recovery
- Postal Service
  - fleet management

METROP/COUNTY/CITY/TOWN AGENCIES
- Metrop/County/City/Town Agencies
  - planning, pavement, and bridge design
- Police/Fire Emergency Services
  - enforcement
  - hazardous materials monitoring
- Transit Agency
  - fleet management

PRIVATE SECTOR

MOTOR CARRIERS
- National/Regnal/Intercity (long/med haul)
  - fleet management
  - vehicle operation
  - driver management
  - tax reporting
  - reducing on-route delays
- Local/Metropolitan (short haul; p&d)
  - fleet management
  - vehicle operation
  - driver management
  - tax reporting
  - reducing en-route delays

RAIL CARRIERS
- TOFC/COFC/RoadRailer Operators
  - terminal management
  - equipment management
- Hazardous Materials Carriers
  - fleet management

MARINE CARRIERS
- Container and Ro/Ro Ship Operators
  - terminal management
  - equipment management

FREIGHT FORWARDERS
- Agents and Brokers
  - fleet management

SHIPPERS/CONSIGNEES
- Manufacturers (just-in-time opertns)
  - fleet/goods management
- Wholesalers/Retailers
  - fleet/goods management

SERVICE INDUSTRIES
- Truck Stop Operators (fuel, repair)
  - credit security
  - vehicle location
- Insurance Companies
  - vehicle safety compliance
  - hazardous materials risk mgt
- Equipment Lessors (truck, rail, marine)
  - equipment management
  - vehicle/equipment operation compliance

MOTOR VEH EQUIPMENT MANUFS
  - market research and vehicle design

Source: FEASIBILITY OF A NATIONAL HEAVY-VEHICLE MONITORING SYSTEM, NCHRP #303, TRB, Dec88.

In the U.S., states which apply weight-distance tax need information on truck weights and truck movements for the administration of these taxes. Accurate and reliable vehicle identification and data on miles accumulated in each state are needed. WIM and AVL equipment or WIM and AVI equipment installed at state lines, along interstate highways and principal arterials could satisfy this need.

Long-haul, variable route carriers need communication services and vehicle location information for equipment (tractor and trailer) and driver management. This could be served by either a nationwide satellite-based AVL service incorporating two-way communication, or an adequately spaced roadside AVI system with telecommunication links covering major truck routes.

Interstate motor carriers need mileage-per-state data for each truck for tax reporting. AVL or a combination of AVI with on-board computers would satisfy this requirement.

Marine, rail and terminal operators are interested in the automatic identification of containers, chassis, tractor and trailer units. Low-cost, durable AVI equipment would satisfy this need, although attention will need to be given to the development of standards to ensure equipment provided by different manufacturers can communicate. Toll facility operators are interested in AVI technology for the automatic identification and payment or billing of tolls.

Weigh station and port of entry operators are interested in improving operations by automatic identification of trucks and automatic verification of registration, operating authority, safety inspections and permit data. This can be achieved through the use of AVI technology linked to a computerized regional database.

Hazardous materials carriers need on-demand communications and frequent vehicle location information for fleet management, security, public safety and emergency response. This can be accomplished with a nationwide AVL system.

In summary, there are a wide variety of markets for heavy vehicle monitoring and management technologies. However, these markets are highly fragmented. The potential for larger integrated markets exists, but will take time to develop.

4.1.3 Further Market Considerations

While the primary focus in the Mobile Information Systems Impact Study [1] was on in-vehicle devices with navigation/route guidance capability, the section on market perspectives was developed with a view to future comprehensive mobile information systems. The potential applications of such devices – which would incorporate also the more basic AVI, AVL, AVM functions – were presented in the following context:

- travel advisory
- mobile office
- fleet management
- occupant activities
- traffic management
- driver/vehicle/cargo monitoring and control.

The primary functions and representative features/content that might emerge within each of the application areas are presented in *Mobile Information Systems Impact Study*, [1] Exhibits 21 to 26, pages 105 to 110 (They are also included in this report in Appendix B: MISIS Selected Exhibits).

For ease of reference, and because of the importance of recognizing the wide range of expected benefits from future comprehensive systems, the Mobile Information Systems Impact report's Exhibit 20 (on page 100) is included here as Exhibit 31. The degree to which equipment designers and developers keep the potential applications in mind, including the benefit areas in which their potential customers are likely to seek returns, will have a significant impact on the market penetration rates of these systems.

It may be expected that – beyond the direct users simply trying to increase the productivity of transport operations (carriers) or make travel less onerous (families and individuals) – the primary forces for implementing mobile information systems will be:

- road safety
- conservation of resources
- environmental protection
- increased fairness.

This means that "indirect users"[5], if they can so be labelled anymore, will play a major role in the market development.

It is not too far-fetched to foresee a situation where installation of AVI transponder units will be legislated (e.g: to take place by next vehicle registration date) – to facilitate, for the first time, both corridor-based and system-side traffic flow monitoring and to assist in the implementation of many transportation system management (TSM) measures which have not been adopted, for various reasons, in the past. The AVI legislation would have to be paralleled by wide scale installation of road-side and in-pavement

---

[5] Indirect users: those who use the information provided by the in-vehicle devices on the road, which transmit on public frequencies or can be polled on demand, to collect traffic or other data, assist in traffic management, control/limit access to certain areas, aid in cargo management, apply user pay, enforce rules of the road, etc.

EXHIBIT 31

PRIMARY BENEFITS OF MOBILE INFORMATION SYSTEMS IN THEIR MAJOR APPLICATION AREAS

APPLICATION AREA	PRIMARY BENEFIT	MEANS OF ACHIEVING
TRAVEL ADVISORY	Minimize costs	optimize route selection & travel timing minimize number of lost motorists
	Increase overall efficiency	provide marketing and community information
	Maximize enjoyment	provide road side + general attractions informtn provide on-board entertainment and education.
FLEET MANAGEMENT	Maximize efficiency	optimize pick-up/delivery path optimize load consolidation
	Improve level of service	monitor vehicle and shipment location
	Increase equipment utilization	predict tractor, trailer and driver availability
	Increase security	provide convoy management and automatic tracking
	Provide management information	accumulate operating statistics
	Increase public transportation productivity	provide information on park&ride facilities provide information on departures and arrivals.
TRAFFIC MANAGEMENT	Utilize corridor capacities more fully	support freeway/arterial traffic mgt systems support preferential treatment of HOVs
	Temper growth in new traffic	support demand management measures: access control, user pricing, etc
	Increase safety	support flow control and incident management improve law enforcement.
MOBILE OFFICE	Extend office capability into the vehicle	provide customer and product lists provide paging, dialing and dictation process invoices, cargo slips, ...
OCCUPANT ACTIVITY	Increase enjoyment	reduce uncertainties related to travel provide access to a vast activity library
	Save money and time	take full advantage of competitive pricing on goods and services.
VEHICLE /DRIVER MONITORING	Increase road safety	diagnose likely vehicle failures early increase vision in all directions monitor driver condition and alert if required
	Reduce vehicle costs	support/teach good driving practices support preventive maintenance program.

Source: Mobile Information Systems Impact Study (Exh 20/p100)
Parviainen J A et al/Parviainen & Associates; for MTO & TDC; August 1988.

interrogator units connected to local data accumulator/processors and the required communication links to the traffic management centre.

Compared to capital investments required to expand road and transit capacity in any significant way, an electronics-based strategy for the road transport sector is bound to prove highly cost-effective – and, this is critical, highly complementary to optimizing any subsequent capacity investments.

In the context of Canadian (and U.S.) metropolitan areas, the focus may become how to apply advanced electronics to the driver/vehicle/road system to increase road safety and in order to best accelerate the implementation of transportation demand management measures (TDM), transportation control measures (TCM), and demand reduction measures (DRM) (whichever category and terminology may be most appropriate). In Europe, the application of in-vehicle/road-side electronics is the next likely frontier in implementing "traffic calming" – a serious, and in the minds of many, last chance possibility to overcome the "fatal attraction" of the automobile.

To help optimize the investments in driver/vehicle/road system electronics – and, particularly, to help identify priority areas – the potential functional capabilities of future mobile information systems will need to be related to (overlaid on top of) the basic trip making/travel demand characteristics (Exhibit 32). This will also help in identifying priority areas in terms of the primary goals of conservation of energy and other resources and of improving air quality.

In order to fine tune the in-vehicle system designs and functional capabilities to match the needs of freight carriers – and shippers and receivers, freight consolidators, warehouses, customs – the freight distribution system will need to be looked at in detail. Mobile information systems, in conjunction with related FMIS (fleet management information systems) and EDI (electronic data interchange) technologies will need to be tailored to meet the specific requirements inherent in factors affecting the productivity of the entire freight transportation/distribution sector (for productivity factors in trucking, see Exhibit 33).

The MISIS report [1] includes a brief discussion on likely preferences of the user communities, on desirable system functions, on barriers and needs, and on Canadian suppliers and market penetration.

EXHIBIT 32

COMPONENTS OF TRAVEL DEMAND

- Passenger and Freight Transportation Sectors -

MODE	SUB-MODE / AREA	TRIP PURPOSE Home-Based				NHB
ROAD	AUTO urban cars st.wagons pass vans	work	school	shop&prsbus	soc-rec&oth	nonhomebasd
	AUTO rural	wrk	sch	spb	sro	nhb
	LIGHT TRUCK urban					
	LIGHT TRUCK rural					
	BUS urban tran u&r school	homebased work	h-b sch	sho pbs	soc rec	non h-b
	MEDIUM TRUCK	gnrl frg + hh prd	bulk &lqd	hm&a &bld	JIT	hndlg w-hsg
	HEAVY TRUCK	gnrl frg + hh prd	bulk &lqd	hm&a &bld	JIT	hndlg w-hsg
	AUTO intercity	pleasure & personal	visit friends relatvs		bsn	wrk
	BUS intercity	plsr & prsl	visit		bsn	BPX
RAIL	PASS RAIL intercity	plsr & prsl	visit		bsn	cargo
	PASS RAIL urban transit	homebased work	h-b sch	sho pbs	soc rec	non h-b
	FREIGHT RAIL	bulk commo-dities	other rail only		inter-modal (tofc)	hndlg & w-hsg
AIR	PASSR AIR	business	visit frnds reltv		pls & prs	air car-go
	CARGO AIR	gnrl cargo	express		guarantd	h&wh
MARINE	PASSR MARINE	plsr & prsl	visit		bsn&wrk	cargo
	CARGO MARINE	bulk commodities	gnrl		intrmd	h&wh
PIPELINE	INTERCITY & URBAN	oil	gas		dry	trmnls

Source: Jouko A Parviainen

EXHIBIT 32 (key)

COMPONENTS OF TRAVEL DEMAND

- Passenger and Freight Transportation Sectors -

Notes:

Automobile includes cars, st. wagons, mini- and other passenger vans and utility vehicles. Light truck includes light cargo vans; medium truck includes heavy cargo vans; heavy truck includes straight trucks, and all combinations of truck or tractor with semis & trailers operated by for-hire and private carriers. Urban transit bus includes specialized transit vehicles (ie. handicapped service vans).

Trip Purposes (abbreviations)

wrk = home-based work
sch (u&r school) = home-based school (urban and rural school)
shop&prsbus (spb) (sho pbs) = home-based shopping & home-based personal business
soc-rec&oth (sro) (soc rec) = social-recreational and other
nhb (non h-b) = non home-based
bsn = business
BPX = bus parcel express
plsr & prsl (pls & prs) = pleasure and personal
visit = visit friends and relatives

gnrl frg + hh prd = general freight + household products
bulk&lqd = bulk and liquid bulk
hm&a&bld = heavy machinery & automobiles & building supplies
JIT = just-in-time
swtch hndlg w-hsg (h&wh) = switching, handling and warehousing
trmnls = terminals
gnrl = general cargo
intrmd = intermodal freight
tofc = trailer on flat car

EXHIBIT 33

TRUCK TRANSPORTATION

* Factors Affecting Productivity *

CARRIER

size: small / med / large
ownership & admin. structure & mgt methods
location: HQ & branches & yards
terminals: few / many
small / large

FLEET COMPOSITION

fleet size
equipment types: pwr units & trailers
trailers/tractors ratio
average & specific ages
specs & options

MARKETS

nature: static / changing
number of customers: few / many
type of custmrs: resources extr. / manufacturers / distributors / dealers / bldrs / contractors / consumers
distribution link (between ... & ...)
customers

DELIVERIES to

warehouses: public / private
manual / fork lift / conveyor
plants: for storage / for production
with 1 / 2 / 3 shifts
job sites
stores
homes

LOADS

number: few daily / many daily
frequency: regular / irregular
type: TL / LTL (small/large)
packaging: loose / packages / boxes&bags / liquid / bulk
shipping: loose / shrink wrapped / pallets & platforms & skids / containers / tanks

NATURE OF PRODUCT

storage: impervious to elements /perishable
seasonality: all-year / seasonable
sensitivity: tough / damage prone
hazard level: benign / hazardous
unit weight: light / heavy

PROTECTION REQUIRED

weather: heat / cold / rain & snow / wind
security: pilferage / vandalism / theft

SERVICE LEVELS

routing: fixed / flexible
schedule adherance: non-critical / critical
pick-up/delivery timing: large buffer / med buffer / very tight (JIT)
tracking: upon arrival only / en-route cont position and condition monitoring
rates: highly competitive / slow response

OTHER OPERATIONAL FACTORS

type & range: city P&D / metropolitan
line haul: short / long
load factor: deadheading & empty units / balanced trips
terminals: routines & hours
customs clearance: pre-cl./at border/inland
dispatching: once-a-day / en-route
drivers: owner-operators / off the board
stable / heavy turn-over
training levels & availability

MAINTENANCE

location: in-house / contract-out
mechanics: training levels & availability
specialized equipment
on-board records: manual / computerized
PM: manual call / micro-computerized FMIS

ENVIRONMENT

competition: truck & rail & air & intermodl
agrmnts: inter-carrier & inter-modl &unions
permits & licences & bonding
safety regulations: driver & cargo (non-mix / dangerous) & vehicle related
taxes: road & fuel & business
road limits: axle weights & width & height
road conditions: surface & winter maint.
road: reconstructn closures & truck routes
traffic: duration & severity of cong.peaks
free trade: carriers & business in general
state of the economy: general & by sector

Source: Jouko A Parviainen

4.2 Vehicular Monitoring and Control Systems

4.2.1 Selected Features, Applications and Specs

a) Engine

Electronic Engine Controllers – Chrysler Motors' Electronic Engine Controller utilizes a Motorola 68HC11 microcomputer to monitor and control engine functions. These functions include distributorless ignition, fuel injection, charging system, idle speed, cruise control, radiator fan control, air-conditioner clutch control and engine related emission controls. To provide reliable operation over a wide range of input voltages, the unit incorporates a DC-to-DC convertor power supply which maintains a constant nine volts to the system even when the input battery voltage drops as low as five volts in a cold-weather cranking situation.

The engine controller has three electronic ignition output drivers and can drive up to three banks of ignition coils in the distributorless mode. It can also operate a single coil with a conventional spark distributor. The unit has three fuel injector output drivers and can function as a single point injection controller or as a multipoint bank injection controller. Automatic Idle Speed control is achieved via a stepper motor throttle actuator. The Serial Peripheral Interface chip (SPI) provides the stepper motor logic signals. An output driver transistor is provided for the radiator fan motor control function. Another output transistor drives the alternator field winding to provide charging system control. Two solenoid output drivers are provided for the vacuum and vent operation of the cruise control throttle actuator.

The analog-to-digital converter portion of the microcomputer measures the knock signal, the oxygen sensor, the coolant temperature, the battery charge level, the manifold absolute pressure and the throttle position.

A Chrysler Collision Detection (CCD) serial data link is incorporated to provide communication to other vehicle sub-systems. Another serial communication interface is available for diagnostics and it can communicate at 62.5 kilobaud and 7812 baud. Fuel usage data is computed from the injector drive information and is communicated on the CCD serial data link for driver information via other sub-systems. The unit is mounted in the engine compartment and intake air flows through the module housing to cool the high power output semiconductors. (For electronic engine controller specs, see Appendix D)

b) Transaxle

Chrysler Corporation's new **Ultradrive** four-speed automatic transaxle is the first electronic transmission in production to employ adaptive controls (to be available for all 3.3 L and some 3.0L V6 engines). Code named the A-604 EATX, this new transmission system communicates with the Engine Controller via a multiplexed data-link. The data-link from the Engine Controller communicates the engine RPM, target idle RPM, engine temperature, battery voltage and engine model code. The electro-mechanical interface with the transaxle consists of four solenoid valves, three hydraulic oil pressure switches and two-shaft speed sensors.

The solenoid valves are three-way poppet valves that have a response time of five milliseconds. They are rated for pressures of 1138 kPa and flows of 7.5 L/s at 690 kPa and 66°C. Two of the valves are normally vented and two are normally applied. The normally applied valves are used in the second-fourth and low-reverse clutches so that the vehicle can limp-in should there be an electrical failure. With no electrical power, the transmission provides second gear in "over-drive," "drive" or "low" shift lever settings. Neutral, Park and Reverse continue to function normally. The pressure switches are used to identify and confirm solenoid function.

The speed sensors measure the torque converter turbine speed and the output (parking sprag) shaft speed. The turbine speed sensor uses a sixty tooth tone wheel and an inductive pickup. The tooth-to-tooth uniformity of the sensor wheel is carefully controlled and provides a very accurate signal that can be differentiated to provide acceleration data. The output speed sensor operates with the twenty-four tooth parking sprag.

All of these electro-mechanical interface components are mounted externally on the transaxle to allow servicing. There are no electrical wires or electronic parts inside the transmission body. The Electronic Transmission Control Computer (EATX) utilizes a surface mount 68HC11 microcomputer from Motorola Semiconductor. The control computer uses 32 kilobytes of Read-Only-Memory and 384 bytes of Random Access Memory.

Application-Specific-Integrated-Circuits (ASICs) are also used. One of the ASIC chips handles the data-link. The data link is a multiplexed serial data link with collision detection provisions and win/lose arbitration based on an identifier byte. The high speed computational power of the 68HC11 permits the use of real-time adaptive control. Speed data is sampled every seven milliseconds. A 500 kHz clock pulse train is sent to latchable free-running counters. When the inductive speed sensor determines that a tooth is passing, the counter is latched and the tooth-to-tooth count is compared to that of the previous sample. The number of teeth between these latched values is divided by the difference to give the calculated speed.

The output speed is used to calculate friction element slip by multiplying output speed times the gear ratio and comparing it to the turbine speed. To execute the shift logic, the computer keeps a continuous record of each friction element apply status. The computer tracks the oil volume in each hydraulic circuit by using predetermined flow rates and learning the fill volume. The computer stores the learned characteristics of four such oil fill volumes. The computer can detect seal leakage and can delay shifting to fourth gear until the transaxle is able to do so. This logic was added to the controller after it was discovered that a small percentage of early production transaxles were incurring internal clutch failures due to a seal leakage problem. Improved seals are now being used, but the computer will retain this monitoring capability as a further safeguard.[6]

Other recent notable developments in transaxles are:

- Porsche's four speed **Tiptronic** – dual function gear box – which has no clutch pedal; the gear selector lever has two planes: left side has standard automatic positions (P N D 3 2 1), the right side manual positions (+ M -) (travel is D<->M) (developed by Porsche/Bosch/ZF based on dual-clutch PDK of the 962C sports racing car)

- Eaton's **CEEMAT** – Converter-Enhanced, Electronically Managed Automatic Transmission – for commercial vehicles which combines a torque converter, power synchronizer, and electronically managed shift control to provide optimum performance and efficiency in severe on/off road applications

- Epilogics Inc's **IVT** – Infinitely Variable Transmission – is a unique hard-geared, high-efficiency transmission which uses no disengagement mechanism, no friction devices or fluid couplings, and provides infinitely variable output and a fully-engaged neutral mode (bench model available for customer testing); by late 1990, plans are to offer dynamic engine braking through all ratios

- Toyota's new automatic transmission **A341E** employs an integrated engine/transmission control system named ECT-i, and a high performance "Super-Flow" torque converter – capable of total control of engine torque and clutch hydraulic pressure during shifting.

---

6) For more details on this system, see the following SAE papers: "The All-Adaptive Controls for the Chrysler Ultradrive Transaxle," by Leising, Holbrook and Benford and "The Chrysler A-604 Ultradrive 4-speed Automatic Transaxle," by Martin and Nogle.

c) Braking

Antilock Braking – Anti-lock braking control is achieved by monitoring rotational speed of the controlled wheel and computing wheel rotational accelerations to derive control information that is used to modulate the brake pressure to the appropriate level. The tire/road coefficient-of-friction (mu) is the ratio between the friction force in the longitudinal direction and the normal (weight) force in the vertical direction. The value of "mu" is determined by frictional properties of the tire and the road surface interface. The coefficient "mu" varies from zero to a maximum of unity. Typical values are between 0.15 and 0.85.

The normal force or weight loading on the wheel depends on the proportion of weight being carried by the wheel being controlled. The pitching action of a vehicle with a high centre-of-gravity causes front wheel normal force to increase and rear wheel normal force to decrease. This is why proportioning valves are used on conventional brake systems.

The braking torque on an undriven wheel is proportional to the product of the braking force due to the hydraulic pressure forcing the brake puck against the brake disk and the radius from the puck to the centre of rotation or axle. The friction torque on the undriven wheel is equal to the product of road/tire friction force in the longitudinal direction and the rolling radius of the wheel. The frictional torque can also be expressed in terms of the vehicle weight on the wheel and the coefficient-of-friction by substituting those terms for the road/tire frictional term. This value can be further described in terms of the vehicle's dynamics to take into account the vehicle centre-of-mass deceleration and the resultant effect on the weight or load being carried by the wheel in question. The dynamic torque of the wheel is equal to the product of the wheel's moment-of-inertia (a constant), and the angular velocity of the wheel. Vehicular linear momentum is also be transferred to the wheel. Slip is defined as the difference between the wheel's actual rotational speed and it's free-rolling rotational speed that would match the vehicle's forward velocity. The lateral or side force of a tire is the product of the road/ tire coefficient-of-friction and the normal force or weight being carried by that tire. The lateral "mu" may differ slightly from the longitudinal "mu" due to tire tread characteristics.

A vehicle can be decelerated in the longitudinal direction only to the extent of the maximum available coefficient-of-friction which can not exceed unity.[7]

In the simplest **control algorithm**, the computer can determine that the wheel is decelerating at a rate greater than the equivalent of one "g" or 9.8 m/s^2 which is the theoretical limit. When this deceleration occurs, the computer can signal the brake pressure modulator to reduce the braking force thus avoiding a locked wheel. This control system would be attempting to achieve a constant deceleration of one "g" and therefore would always be applying too much braking force because the actual tire/road value of "mu" could be 0.15 or less.

Some anti-lock control systems use **solenoid valves** to control the brake pressure. An isolation valve is used to isolate the hydraulic circuit of the wheel away from the master cylinder pressure. After the isolation valve has had time to close, a dump or decay solenoid is activated to bleed off the pressure on that wheel's brake cylinder. Closing both solenoid valves, the isolation and the dump valve, will hold a constant brake pressure. To re-apply pressure, the dump solenoid must be closed before the isolation valve is reopened. Bendix refers to the isolation valve as a build valve because it builds the pressure when it is opened. Systems with on/off controls tend to cause a very noticeable shudder or vibration in the vehicle due to the cycling of brake pressure on and off at rates of eight to fifteen times per second. Faster acting hydraulic control solenoids can increase the frequency and turn the shudder into a hum. Anti-lock brake control systems using an on/off pressure modulator can use an undriven wheel's rolling acceleration during the off-cycle to compute an estimated value of "mu." The new value of "mu" is then modified allowing the control system to adapt to a different road/tire coefficient-of-friction. The ability to adapt to the actual tire/road coefficient-of-friction is essential in the real world where patches of ice or oily spots are encountered.

A more sophisticated anti-lock system will adapt to the "mu" at each wheel. If, for example, the left wheels are on dry pavement with a "mu" of 0.8 and the right wheels are on an icy patch with a "mu" of 0.1 then a yawing moment would be caused by unequal braking forces. If the vehicle has a large moment of inertia about the vertical axis, this yaw will occur slowly enough for the driver to compensate by turning the steering wheel. A sub-compact car with a smaller wheel base and lower moment of inertia might yaw out of control and go into a spin during a panic stop under these conditions. The Bosch ABS controller compares the left and right wheel behaviour

---

7) The Tire Axis system is defined in Volume 4 of the SAE Handbook on page 4:34.213, Vehicle Dynamics Terminology SAE J670e.

during anti-lock control and modifies the brake pressure build cycle on the high "mu" side to delay the onset of yaw so that the driver can respond appropriately.

The second derivative of wheel speed or the rate of change of acceleration is termed "jerk." This term is computed to provide leading information about the wheel's acceleration or deceleration. Jerk data tends to be very noisy but the mere change in polarity of this term can signal the wheel's changing deceleration.

Control of a driven wheel is somewhat different due to the drive-train interactions. Some systems use an undriven wheel as a reference while controlling the driven wheels. On very slippery road surfaces, the drag torque of the engine can have an adverse affect on anti-lock braking performance. The anti-lock control of braking torque alone may not be able to compensate for the drag torque from the drive train. The anti-lock braking system therefore needs to communicate with other vehicle subsystems to either disengage the transmission if it is under electronic control or to control the drag torque of the engine by modifying the engine RPM via the electronic engine control computer. Bosch uses this electronic engine throttle control to compensate for drag torque only if high slip conditions occur. Driving stability and steerability are substantially improved under snow and ice conditions.

Four-wheel drive systems add more complications to the anti-lock control system. When the centre differential is locked, the average speed of the front wheels is then equal to the speed of the rear wheels. When the rear axle differential is locked the two rear wheels are rigidly coupled and forced to rotate at the same speed. In 4-wheel drive, all of the wheels are dynamically coupled to each other and the engine drag torque and moment of inertia act on all wheels. Under split "mu" conditions the rear axle differential lock produces an increased yaw moment. The central differential lock effect eliminates the possibility of using the behavior of an undriven wheel as a speed reference or a "mu" reference. A radar speed sensor would be a nice thing to have in this situation. Some alternate speed sensing is needed if the 4-wheel drive transmissions remain locked during anti-lock braking. Bosch uses a longitudinal accelerometer switch to detect when a road/tire coefficient-of-friction less than 0.3 is encountered.

Anti-lock braking cannot be optimum with all of the wheels coupled together by the locked differentials even with engine throttle control and an automatic shift to neutral. While not optimum, an ABS system can still be very helpful under those limitations. If the 4-wheel drive differentials are electronically controlled, then they can be disengaged during panic stop anti-lock system operation. If the 4-wheel drive system does not have a rear axle lock and the central differential incorporates a free-wheeling viscous clutch, then the wheels can be suitably decoupled during anti-lock braking and the adverse affects are mainly eliminated.

The Bendix Anti-Lock System used on Chrysler passenger cars controls the braking action of all four wheels. At 97 km/h on wet asphalt with a "mu" coefficient of 0.6, the system stops a typical vehicle in 60 metres as compared to 80m for a locked wheel skidding stop. On dry pavement, there is substantially less improvement; however on snow or ice there is dramatic improvement. At 48 km/h on an icy surface with a "mu" of 0.2, the anti-lock brake control system stopped the vehicle in 27 m as compared to 43 m with locked wheels. The Bendix system utilizes an Intel MCS 8096 microcomputer chip for the real time computational work and a National Semiconductor COPS-640 for the watch-dog functions. The MCS-8096 microcomputer has four built-in capture registers that provide a ready means of monitoring the four wheel speed inputs. It also has 8000 bytes of ROM for the main program storage and 232 bytes of RAM for use during computations. It can perform a 32 by 16 bit divide in 6.5 to 12.5 microseconds (μs).

Control Algorithms – Immediately upon the application of power, the microcomputer is reset, the random access memory is cleared, the stack pointer, other registers and the watch-dog are initialized. The main program loop is executed at a prescribed rate of about 5 milliseconds (ms). Data for wheel speed calculations is acquired during the main program loop through high speed interrupts that service the inputs from the wheel sensors. Vehicle speed, deceleration and road surface coefficient values are computed in the main loop. During the time that the anti-lock mode is active, the wheel speed, analysis and valve action sub-routines are sequentially called for each of the four wheels. The wheel speed sub-routine uses the count information taken during the main routine interrupts and calculates the actual speed and acceleration of each wheel. The sub-routine is able to perform these calculations in about 60 microseconds.

The analysis sub-routine determines the state of operation and establishes the command to change the state of operation. The Bendix system has four states for each wheel. State 1 is defined as the wheel being in deceleration but not in the pressure decay mode. State 2 is in deceleration and in pressure decay. State 3 is in acceleration and in pressure decay. State 4 is in acceleration and not in decay mode.[8] (For state descriptions and specs, see Appendix D.)

Traction – Traction control is a logical extension of anti-lock or anti-skid braking control. The same road/tire frictional force that limits braking deceleration also limits

---

8) The SAE Handbook describes the road test code for Wheel Slip Brake Control Systems (SAE J46). The Minimum Requirements for Wheel Slip Brake Control System Malfunction Signals is suggested in SAE J1230.

the traction acceleration. When the driver attempts to accelerate his vehicle with excessive throttle, the driven wheels may spin. Because each of the driven wheels may be encountering a different tire/road coefficient-of-friction, "mu," the drive-train differential will send more drive torque to the wheel that has the least traction. This unbalanced traction may cause fish-tailing of a rear-wheel drive vehicle. A traction control system attempts to optimize the traction of each driven wheel and improve the lateral stability.

Both Bosch and Volvo have developed impressive production traction control systems. Mercedes and BMW use the Bosch system. Volvo's Anti-Skid/Traction control system uses a 16 bit microcomputer and communicates with both the engine control computer and the automatic transmission control computer via serial data links. During traction control, it is necessary to electronically control the throttle via this data link. The anti-skid brake control components come into play during traction control to balance the left and right traction by braking the wheel with insufficient traction so that the drive-train differential will send torque to the wheels that can use it. Traction and lateral forces are both related to the wheel spin or slip rate. Optimum traction is achieved at slip rates of around twenty percent and reasonable lateral force is still present at this slip rate.

During traction control system operation, data from the four wheel speed sensors is compared to determine if excessive slip or spin is occurring. If the driver has depressed the accelerator pedal too far, the traction control system signals the engine control computer to reduce the engine torque. This can be accomplished by altering the spark, fuel injection, turbo-boost or by altering the throttle body air flow. The Volvo system reduces engine torque in stages. If turbo-boost is on, the turbo-boost is shut off. Then fuel injection to the cylinders is turned off sequentially until the engine torque delivered to the drive-train is within suitable traction capability.

In the BMW system provided by Bosch, the engine torque is reduced by several means. An electronic throttle control is used for the primary control. The throttle opening is reduced step-by-step until a lower limit determined by vehicle speed is reached. Since the engine output torque may not respond rapidly enough through throttle control alone, the fuel injection and ignition is interrupted until the throttle control sub-system can manage. Spark timing can also be retarded by the system if required.

Vehicle lateral stability is retained when the drive-train torque to the wheels has been reduced sufficiently to prevent wheel spin. At the same time as engine torque is being managed, the anti-skid braking control components are used to brake any wheels that are tending to spin. If the road/tire coefficient-of-friction seen by the wheels is different from one wheel to another, the wheel with the lowest coefficient-of-friction would determine the traction limit. By braking that wheel slightly, the other wheel, which has a better coefficient will receive some torque from the differential.

This use of the individual wheel brakes makes the vehicle's differential perform like a mechanically locked differential. The engine control computer provides throttle position and engine RPM information to the anti-skid/traction control computer via the serial data link.

The world's first electronic traction control system (TCS) for front wheel drive automobiles was offered in Honda Legend (Cadillac is offering its own TCS in the 1990 Allante). Honda's is a 3-way multi-control system via engine, transmission, and brakes – each subdivided into functions:

- engine control may encompass any of: throttle, fuel injection, ignition timing, active cylinder and/or boost control
- transmission control may include: clutch control, two-wheel-drive to/from 4-wheel-drive changeover, and differential lock control
- brakes: the driving wheels' brakes may be controlled separately or simultaneously.

It controls traction during acceleration on slippery surfaces and during cornering and on irregular surface conditions. The TCS modulates engine power through fuel flow level and ignition timing control. The system has two types of sensors: wheel-speed sensors (shared with Honda's own ABS) and a steering-angle sensor which feeds signals to the TCS electronic control unit (ECU), which performs the math, and transmits signals to PGM-F1 (programmed fuel injection control).

On full-time four-wheel drive vehicles, traction control includes the division of torque between the front and rear wheels for maximum traction and stability. General Motors' German subsidiary, Opel, markets the Opel Vectra 4X4 which uses a viscous coupling in the central differential to divide the torque between front and rear wheels. Starting out in low gear on a dry surface, the Vectra initially provides all torque to the front wheels and as you shift through the gears, the rear axle gets an increasing proportion of torque up to sixty percent rear and forty percent front. This portion of the traction control is not electronically controlled. It is provided by the design of the viscous coupling. An electronic clutch is included in the Opel Vectra's centre differential to disengage the rear wheel drive during ant-skid braking system operation.

Audi Coupe Quattro system incorporates three separate differentials – front, rear, centre – which compensate for differing wheel speeds and drivetrain wind-up. A torque-sensing Torsen differential in the centre automatically distributes torque between front and rear wheels (in a 50/50 to 78/22 range). During low speed driving (< 24 km/h) in difficult conditions, driver can lock the rear differential manually for extra grip; above that speeds rear differential is automatically unlocked and the anti-lock braking system reactivated.

A future version of Bosch ABS 2U will offer hybrid-technology ECU that is fitted directly to the hydraulic modulator. By reducing the number of cables, plugs and sockets, and improving package-methods, installation will be easier and less expensive. The microprocessor based ECUs have two independently functioning self-diagnosing computers for system reliability and safety. Bosch has also developed for commercial vehicles, which have neither EDC (Electronic Diesel Control) nor EMS (Engine Management Control), an ASR system which has a servo motor acting directly on the diesel fuel-injection pump (also self-adapting between 12V and 24V).

d) Driver Information Systems

Oldsmobile System – The Oldsmobile Driver Information System provides fifteen trip computer functions selectable by the driver (for specs, see Appendix D):

- "Range" displays the estimated driving range based on the amount of fuel in the tank and the average fuel economy over the last 10 miles. If the range is less than 50 mi, the message "Low Driving Range" is displayed.

- "Econ" displays the fuel economy average since the last reset of this function. Pressing the "Econ" button a second time causes a display of instantaneous fuel economy.

- "Gages" displays coolant temperature on the first push, tachometer on the second and battery voltage on the third.

- "Oil" displays percent oil life remaining. When the remaining oil life is less than ten percent, the distance to next oil change is displayed.

- "Fuel" displays accumulated consumption since last reset.

- "Dest" displays distance to preset destination distance.

- "ETA" displays the estimated-time-of-arrival based on the distance to destination divided by the average speed.

- "E/T" displays the elapsed time since the last reset of this display.

- "Speed" displays average speed since the last reset of this function based on accumulated distance and ignition-on time.

- "E/M" allows the selection of English or metric units for any of the displayed functions.
- "Date/Time" displays date on first push and displays time for five seconds on second push.

The Driver Information System utilizes a surface mount microcomputer and 17 character dot-matrix display using vacuum-fluorescent technology. It monitors the analog fuel level sensor for fuel data but receives the balance of its data via a serial data link from the GM Engine Control Module.

4.2.2 New Technologies

New technologies will play a very important role in the automobile of the future. New materials and new engines will have a major impact; however, this study is primarily concerned with electronics, so therefore only the new electronic technologies will be addressed.

a) Computers and Processors

Just as large-scale integration (LSI) made the microcomputers feasible, further size reductions, using **sub-micron semiconductor structures**, will allow even more complex computers-on-a-chip. The limits of photo-lithography have already been reached in semiconductor processing; therefore new processing machines are being developed to make use of electron beam lithography which will allow the fabrication of smaller structures on the silicon semiconductor micro-chips.

New computer architectures are also being introduced which will offer more powerful features. One new approach already available is the DSP, **digital signal processor**: this device, pioneered by Texas Instruments, uses a high speed multiplier and is designed to handle mathematically intense algorithms at real-time speeds. Single-chip DSP devices have a throughput in excess of forty million floating decimal point operations per second. The Lotus active suspension system utilizes a DSP chip. Experimental anti-lock brake controllers have also been devised with this technology.

DSPs are being widely utilized in communication products to implement adaptive signal filters, noise cancellers, voice recognition and video image processing products. Noise Cancellation Technologies, of Great Neck, N.Y., is using a Texas Instruments DSP in a new electronic muffler experiment. Chrysler Corporation and I.T.T. Intermettal of West Germany are working together developing specialized DSP chips for car radio applications. DSP is also being investigated in anti-knock control where it can recognize the complex sound patterns associated with incipient knock conditions.

DSP devices use some parallel processing concepts and extensive pipe-lining to speed up its operation. Instruction fetching, decoding and execution operations are performed in parallel instead of sequentially. This allows a DSP chip to perform a multiplication, addition, shift or data move in a single machine cycle. A conventional microcomputer would require several machine cycles. As design engineers become more familiar with DSP principles, we will see a proliferation of applications. Other parallel computing architectures will be forthcoming that will allow higher speed computation of complex algorithms. Mega-byte memory chips offer more program storage capability than before.

New **integrated circuit (IC) chips** are being introduced that will simplify the data links and multiplexed wiring systems of future vehicles. ICs have changed electronics design: because transistors are integrated into gates, and the gates into higher level functions, designers can focus on higher level characteristics. Prices have also fallen dramatically: from $0.25 per transistor to $0.000001 (in very large-scale ICs). The SAE Recommended Practice J1850 is an early step in establishing a standard data link protocol for automobiles. In Europe, several car-makers are adopting the Bosch/ISO Controller Area Network (CAN). U.S. semiconductor suppliers like the CAN concept and Intel has introduced their 82526 CAN chip to support this approach. This new integrated circuit will be used in some 1991 European vehicles. Motorola Semiconductor and NV Philips of Holland are also licensed to produce this new I.C.

b) Expert Systems

New computer programming languages and techniques will bring about more powerful Artificial Intelligence or **Expert System applications**. Whereas conventional digital computer programming deals with absolute certainties of yes and no, the so-called expert systems deal with uncertainties and probabilities to arrive at answers. These are knowledge-based systems that use heuristic (learning) methods to arrive at decisions. The learned path or fuzzy logic sequence is remembered by the Expert System so that it can handle similar solutions more rapidly the next time it encounters similar input data.

Expert Systems are being investigated for medical symptomatic diagnosis. General Motors and IBM have been working together on an Expert System for fault-free diagnosis of automobiles. Fujitsu, NEC and a few other semiconductor firms have announced new fuzzy-logic chips incorporating some 65000 neuro-type elements. These new VLSI chips should have a dramatic impact on Artificial Intelligence product designs. Nissan's electronic total control system for Neo-X employs fuzzy logic, neural network, and intelligent control of engine output and transmission shift characteristics. Some of the related developments, although their automotive applications may be further in the future, include superscalar embedded microprocessors such as Intel's i960CA - which, in addition to the CPU, contains program and register file caches, fast data RAM, flexible system-bus interface, high speed I/O channel processor, and a low latency interrupt control unit (600 000 transistors in all).

c) Sensors

Texas Instruments has developed a new **electronic pressure sensor** capable of measuring the in-cylinder pressures of an internal combustion engine (IMEP, or indicated mean effective pressure; apparent rate of heat release). This sensor would permit the development of an electronic engine controller that could optimize the combustion efficiency of each cylinder. Hitachi has developed a glass fiber-optical sensor that is fitted inside a special spark plug to permit photo-electronic observation of the ignition combustion flame pattern inside the cylinder. This technique could also be utilized to optimize combustion.

Other sensor developments include:

- electronic oil-level sensor which contains a thick-film ceramic circuit board (Engine Electronics Inc operates from -40°C - +150°C, is 100% solid state design, and claimed to be more accurate than analog sensors: floats and thermistors)

- optoelectronic refractometer sensors for on-board (or garage) measurement of battery charge states and antifreeze concentration (Battelle)

- fibreoptic tactile sensing cable suitable as cut-out switch in electric-powered windows, outside the steering wheel (snooze monitor?), and in dashboards as a touch-sensitive switch (Battelle)

- all-electronic air bag sensor – which, by utilizing an accelerometer and digital signal processing technology, can monitor many crash parameters from a single point within the passenger compartment (compared to a mechanical systems that requires several sensors that can monitor only two or three parameters)

- an antenna that operates in the millimetre-wave frequency range (continuous wave signal) and whose beam can be steered by diffraction electronics – for use in automobile radar systems; initially to generate sight or sound warnings, later some direct avoidance control may be possible (Battelle)

- infrared sensor: light reflected from the driver's eye back to a detector to monitor eye blinking – to alert about drowsiness (based on tendency to delay blinks when highly alert and performing observations or control tasks)

d) Diodes

Higher power **solid-state semiconductor laser diodes** are being developed that can lead to short range laser radar applications. This could lead to station-keeping cruise control, blind spot monitoring and other automotive uses.

Higher power **light emitting diodes** (LEDs) are also being introduced. The semiconductor industry believes that they can develop an LED stop light for automotive use.

e) New Displays

Reconfigurable displays will become much more commonplace. New display technologies are being pursued that will find use in vehicle monitoring system display applications. **Cathode Ray Tube** (CRT) displays will find increasing automobile applications. Delco Electronics' installation on a concept vehicle includes six CRTs:

- primary CRT directly in front of the driver, to handle driving information -> single-gun with fixed colour zones using burn-resistant phosphors (to ensure brightness in direct sunlight); monochrome graphics controller (MGC) is microprocessor-based (6802) video generator capable of driving several types of pixel-based displays and of interfacing with another computer (serial data link) and receiving information directly from sensors

- secondary CRT in the centre of instrument panel, a reconfigurable interactive CRT for display and control of climate and audio controls, trip monitor and computer, powertrain gauges, and miscellaneous information (calendar, event reminder, etc.) -> a colour, infrared switch matrix (5 x 5 grid superimposed on display area) controllable-intensity display with eight backlit pushbutton hardswitches for page selection; controller provides video information for each page and provides a gateway between the two main information serial data-links

- CRT dedicated to in-vehicle navigation -> vector-scan monochrome CRT; could be readily integrated into the secondary CRT

- three independent, closed-circuit CRTs for rear vision placed in cockpit (standard mirror) positions; necessary due to vehicle's aerodynamic design (Cd = 0.195) that prohibited rearview mirrors and incorporated a high rear deck; flat panel colour technology probably more functional in future applications.

Nematic curvilinear aligned phase (NCAP) liquid-crystal displays are flexible, bendable and economical to produce. The use of pleochroic dyes allows the display segments to be a deep black in the off-state. Selectively placed colour reflectors provide a vivid contrast when the segments are in the on-state. Twisted nematic liquid-crystals are already in many Japanese automotive applications. The limited operating temperature range and limited viewing angle problems haven't been totally solved but reasonable performance specifications are now being achieved. Flat Screen Display technology has been long awaited and many suppliers are investing heavily in this technology. LCD, **Liquid Crystal Displays**, and EL, **Electroluminescent Displays** have both received some market penetration in lap-top personal computers. Multi-colour LCD screens have also been marketed in small pocket TV sets.

Plasma technology has been used in several fairly large military flat screen applications. Today's large-scale analog vacuum fluorescent displays (**VFDs**) use thin lightweight glass (accomplished by glass posts instead of reinforced glass) and self-standing grid (SSG) construction which allows applications of complicated graphic design patterns (freedom for the grid to be located at any position). Since a VFD is a self-emissive display, the analog bar-graph segment can be illuminated in several ways by using different drive methods.

Recent progress has also been made with **matrix-addressed cathodoluminescent flat CRT technology**. A 3.38 x 3.38 inch unit only 1/8 inch thick has been demonstrated with 300 colour elements per inch, with three colours per pixel, this equates to 100 pixels, or picture elements per inch, a resolution of 380 x 380 pixels. The Advanced Technology Division of SRI International in Menlo Park, California is pursuing this research.

Liquid crystal technology has produced experimental windows for homes and offices that can vary sunlight transmissivity in accordance with an electrical voltage. Some Japanese concept cars have included the idea for a sun roof. Mass production of this technology could bring the costs low enough to permit wide usage in cars. This investigator feels that this is at least a decade away.

Optical techniques are being investigated to display virtual images. Military helicopter pilots now use helmet mounted virtual image generators magnifying images from miniature CRTs. **Heads-up displays** are all ready being introduced into a few GM cars and into some Japanese concept vehicles. The GM Head-up-display makes use of a virtual image projected optically from a vacuum fluorescent display to the windshield. The unit was developed by Hughes Aircraft, Delco and Oldsmobile, CPC-Advanced Vehicle Engineering and was first installed on the Oldsmobile Cutlass Supreme Indy 500 Pace car parade convertibles.

Battelle's unit uses only two holographic elements and incorporates all lenses and aberration correction into them. No special light sources are required; it can operate on a variety of broadband sources, including video and gas discharge displays. The image is created at about three metres, at which distance the human eye is still focused in the far-field. MRHS, Muth-Roberts Heads Up Display System, is a low cost unit ($50 each) which generates an analog, sweep-style speedometer display that appears in the lower quadrant of driver's field of view – about 1 m 20 cm from his eye.

f) Engine Technology

Multi-valve engines with four valves per cylinders are now being introduced and should be commonplace in the early 1990s. In Audi Coupe Quattro, this design increases valve area by 35% thereby improving cylinder charging: the gas flow increases by 25%, improving mid- and top-end performance. Because of the cross-flow head design, centrally located spark plugs and selective individual cylinder knock control, a compression ratio of 10.3:1 can be used. Wide use of electronically controlled valve timing is still some ways off production model vehicles.

Audi's 2226-cc five-cylinder engine, which also incorporates a water-cooled turbo-charger, has five valves per cylinder; compared to the effective area with two valves per cylinder (as 100%), a 4-valve design increases valve area to 150% and 170% (intake/exhaust), and a 5-valve design to 170% and 182%.

Two-stroke engines are receiving a lot of attention. Ford, GM and Chrysler are all known to have active programs for two-stroke introduction in the early to mid-1990s. Orbital Engine Co. of Australia is a recognized leader in this category. New electronic engine controllers are already being developed for two-stroke engine applications. Toyota's S-2, under development, employs four poppet valves per cylinder (instead of being valve-less) and supercharging for forced scavenging. It is reported to produce 60 bkW JIS net and 167 N.m/l torque.

Variable stroke/compression ratio, five-cylinder engine (CVS) is in prototype phase in Australia. It varies its stroke length and compression ratio simultaneously. Developer claims 25% less fuel consumption than a conventional 2.5L engine (due to its ability to shrink its displacement when little power is required; eg: idling or decelerating in city driving). Present compression range is 9:1 – 10:1, but experiments are starting on an astonishing 9:1 – 14.5:1.

Flexible Fuel Engines – GM and Ford are both marketing special fleet vehicles that are capable of running on methanol, gasoline or a mixture of both. The State of California and the City of Los Angeles are encouraging the use of these vehicles as a means of reducing SMOG. Methanol burns much cleaner than diesel or gasoline.

The GM system determines the fuel mixture or blend by measuring the dielectric constant of the fuel with a capacitance sensor. The Ford system uses an optical sensor that relies on the refractive index of the blended fuel. Chrysler is experimenting with a similar technique. The Electronic Fuel Injection control system alters the fuel/air ratio accordingly. It accomplish this by varying the fuel injector pulse width.

Methanol has less energy than gasoline so the injector pulse widths are increased to inject more fuel as the methanol content in the blend is increased.

Methanol is corrosive to conventional fuel system components so these flexible-fuel vehicles use stainless steel tanks and fuel lines. Plastics that are alcohol-safe replace the material in a few other components such as the fuel-level sensor. Flame arresters are installed inside the fuel tank to prevent spontaneous combustion of the methanol vapor.

g) Suspension Technology

The Lotus vehicle suspension system which makes use of the new Digital Signal Processing chip technology is the archetype of active suspension systems (Exhibits 16a and 16b). The publicity it generated certainly accelerated other developmental programs. The system controller is a general purpose microprocessor. The heart of this active suspension system is the DSP chip. The processor indicated in the diagram is a TI TMS-320 DSP, with a throughput of 10 MIPS (million instructions per second), it can perform a 16 bit multiplication and accumulate in 100 nanoseconds. The latest versions of this device can handle 32 bit operations at twice this speed.

TMS-320 DSP receives wheel hub displacement signals from each hydraulic actuator as well as vehicle lateral acceleration and forward velocity. It takes into consideration the body dynamics of pitch, roll and heave, and sends output signals to the servo control valves on the four hydraulic actuators.

The Lotus system can handle vehicle suspension vibrations up to 15 Hz. At 10 Hz, a 10 cm peak to peak harmonic motion will involve accelerations of 20 "g". To reduce hydraulic circuit response times, the system uses two hydraulic accumulators, one at each end of the vehicle. Its servo valves can respond in about 12 ms which relates to about 80 responses per second.

In a fully active suspension system, there are no mechanical suspension springs or dampeners. These conventional mechanical components are replaced by the hydraulic actuator. Each wheel is individually controlled by an actuator. The computer software controls the actuators via the servo valves. The effective spring constant and dampening rate can be altered by the software controlling the hydraulic actuator. Mitsubishi's active suspension control system for the Galant is probably one of the more sophisticated electronically controlled active suspensions in current passenger car production application. Seven sensors supply information about the vehicle speed, rate of turn, braking action and shock-absorber height to the suspension system control computer. The computer sends out control signals to raise or lower the pressure in the struts or to vary the shock-absorber valves to adjust the damping rate. This system uses air-suspension actuators, instead of the high pressure hydraulics used by Lotus, therefore the response time is a little slower, about one hundred milliseconds. The air spring rates as well as the damping rates are varied as the vehicle speed and cornering loads change and a very smooth ride results.

General Motors is incorporating a fast response hydraulic active suspension system on special versions of the new Corvette. This system should perform like the Lotus version.

There are many other electronic **semi-active suspension systems**, that are not fully active in the manner of the Lotus system. These systems retain conventional springs and use special shock absorbers wherein the damping rate can be controlled by electronics. A typical system uses small gear-head servo motors to adjust the orifice inside the shock. The driver can select a soft or firm ride and the computer will signal the orifice control motors to set the shock absorbers accordingly.

Other semi-active systems use air pressure to adjust the shock height; this offers automatic levelling and allows the vehicle to squat on command. In dynamic operation, these systems can also provide some roll control. However, these systems do not have the response rates of the fully active system – but they can provide substantial ride improvement over conventional mechanical suspension systems [17 and 18].

Rolls-Royce Silver Spirit II and Silver Spur II, and three Bentley models, now use an automatic ride control (ARC) system to create an adaptive suspension. An ECU using a microprocessor and vertical, longitudinal and lateral accelerometers is linked to a chain of sensors (reaction time = 0.01 s). The system monitors acceleration, road surface condition, braking and steering inputs. The processor continually receives messages from accelerometers in the ECU and from a series of transducers and switches, comparing the information with preprogrammed threshold values for each switching parameter. Damper settings alter if threshold values are exceeded.

Of significant importance, is the long term potential for reduction of road damage by heavy vehicles, through the use of active suspension systems which would reduce the dynamic road loads caused by non-optimal conventional suspension designs. A corresponding reduction in rolling resistance would also occur which would bring about an improvement in fuel economy. Roll over accidents should also be reduced by the incorporation of a well designed active suspension system. These three factors provide good motivation for the development of active suspension systems for heavy duty vehicles.

The operating life of existing conventional heavy-duty vehicles is such that several decades will pass before the highways see the potential benefit of reduced road damage. The development of a practical active suspension system for heavy-duty vehicles will require the development of new hardware. The tractor-trailer combinations require that the trailers be equipped with an independent system that can operate when pulled by a conventional tractor. Conversely, the tractor's active suspension control system must have the ability to operate effectively when pulling a conventional trailer. Initially, these systems will be expensive and safety may be the only offsetting benefit to the fleet operators who will bear the costs in the marketplace.

4.2.3 Market Considerations

a) Introduction

Market research for automotive electronic vehicle monitoring and control systems is conducted in a variety of ways by the automotive manufacturers. Visits are made to dealerships and the sales personnel are interviewed. Telephone surveys are conducted. Special market surveys are conducted at regional clinics. Consumers are shown prototypes, models, artifacts or artist sketches of potential new product groupings and the public is interviewed or asked to fill out questionnaires. Auto shows are a common site for such activity because new concept vehicles are frequently on display and these shows are open to the general public.

The demographics are very important to the automobile maker and this market research information is carefully studied as the various car-line standard versus optional equipment marketing plans are developed.

There are obvious geographic biases involved in market research. The southern states buy more air conditioned vehicles. The northern latitudes buy more rear window defroster and additional rust-proofing (by/through dealer) options. The Canadian market is generally driven by price and practicality. The California market is biased more toward sports cars.

The age of the market survey respondent is another key factor; older respondents, age 55+, show interest in tire pressure monitoring whereas respondents under 35 do not. High income respondents show more interest in luxury options.

Women are clearly more interested in safety features and service-due reminders than the male respondents. Male respondents show interest in tachometers and turbo gauges. Market surveys also show certain optional equipment biases related to the size or type of vehicle. Sports car buyers tend to like conventional round dial gauges whereas the larger car buyers tend toward the digital electronic instrument cluster. The car-makers therefore attempt to determine the respondent's buying intentions or car size preferences. These are categorized by sub-compact/compact, mid/mid-specialty, luxury/large, van, or light truck "intenders." It is difficult to compare different market surveys without full knowledge of the artifacts shown to the respondents and the demographics of the responding population.

b) Selected Survey Results

At a San Diego clinic on mini-vans, Chrysler Motors obtained information on vehicle monitoring features most desired by the visiting public (Exhibit 34).

Chrysler conducted a telephone survey of 669 owners of vehicles equipped with the highly controversial Electronic Voice Alert. These owners had owned and operated the talking cars approximately one year. According to this survey:

- 94% of respondents satisfied or very satisfied.
- "Low Fuel," "Lights on," and "Keys-in-ignition" were the best liked messages.
- "Fasten your seat belts" and "Low washer fluid" were the least liked messages.
- "Parking brake on" and "Door ajar" were rated in mid-range.
- 75% of respondents would have liked to have "Oil level," "Headlamp burned out" or "Low Tire pressure" as additional messages.
- 94% said they would purchase again the Electronic Voice Alert as an option at a $50.00 cost.
- Women tended to rate the E.V.A. higher than male respondents.

[Source: Chrysler Motors internal report]

GM conducted an employee survey to determine what type of information drivers expect to have displayed and whether it should be displayed continuously or be available on request. The results are presented in Exhibits 35 and 36.

4.3 Travel Support Systems

Two demonstration systems, perhaps best representative of the direction in which travel support technologies in North America may be expected to head, are summarized in the following.

EXHIBIT 34

VEHICLE MONITORING INFORMATION MOST DESIRED

	Male (%)	Female (%)	Avg. (%)
Coolant temperature	90*	72	87
Fuel level remaining	86	86	86
Engine oil pressure	87*	73	85
Engine oil level	74	79	75
Parking brake status	70	77	71
Headlights on when exiting vehicle	63	90*	67
Keys left in ignition when exiting	59	83*	63
Low battery	63	55	62
Coolant level	59	56	58
Electrical malfunction	57	58	57
Door Ajar	47	79*	53
Brake lamps out	50	68*	53
Brake fluid level	50	61*	52
Tail lamp out	47	70*	51
Headlight out	45	67*	48
Low tire pressure	46	49	47
Low transmission oil	44	58*	47
Trunk or rear hatch ajar	41	70*	46
Brake disc pad worn	44	51	45
Seat belt status	38	69*	44

Note that the number of male respondents was greater than the number of female respondents; therefore the average respondent data column is weighted toward the male respondent.

The * denotes responses showing strong bias based on respondents sex.

EXHIBIT 35

CONTINUOUSLY DISPLAYED INFORMATION

* GM Employee Survey *

Parameter	% of Respondents
Speedometer	97
Fuel level	88
Time/clock	85
Oil pressure	69
Tachometer	62
Battery voltage	52
Odometer	52
Coolant temperature	52
Oil temperature	44
HVAC status	41
HVAC temp. setting	39
Trip odometer	33
Radio station	32
HVAC fan speed	30
Date	29
Cassette tape direction	29
Compass	25
Stereo speaker balance	14
Instantaneous gas mileage	13
Stereo tone setting	12
Interior temperature	11
Air/Fuel ratio	11
Brake fluid level	10
Outside temperature	9
Average gas mileage	5
Windshield washer fluid level	4
Tire pressure	4
Average speed	3
Relative humidity	2
Barometric pressure	1

Source: SAE paper 890287

EXHIBIT 36

INFORMATION NOT CONTINUOUSLY AVAILABLE

* GM Employee Survey *

Parameter	% of Respondents
Average gas mileage	78
Windshield washer fluid level	72
Average speed	70
Brake fluid level	70
Stereo speaker balance	70
Radio station	70
HVAC temperature setting	68
Stereo tone setting	67
Outside temperature	67
Trip odometer	67
Interior temperature	65
HVAC fan speed	65
Instantaneous gas mileage	62
Cassette tape direction	60
Tire pressure	58
HVAC status	56
Date	53
Compass	51
Coolant temperature	50
Oil temperature	50
Battery voltage	49
Odometer	47
Air/Fuel ratio	43
Relative humidity	36
Oil pressure	35
Barometric pressure	30
Tachometer	27
Time/clock	14
Fuel level	13
Speedometer	2

Source: SAE paper 890287

4.3.1 G.M. Mobile Information System

General Motors has presented, in connection with recent annual meetings (TRB & SAE), preliminary plans for a travel support system. The Mobile Information System (Exhibit 37), installed in a Cadillac Seville, integrates the following demonstration hardware in a vehicle (the installation method itself yields interesting clues to implications of in-vehicle devices in general):

- a liquid crystal shutter, reconfigurable display with an infrared touch screen as the driver interface (radio and heating/ventilating control heads were removed, underside of instrument panel modified, and a 9 in diagonal, 11 in deep CRT installed in the centre of the instrument panel)

- seven dedicated switches for selecting specific features were installed just below the display; from right to left they provide access to: voice control training program/ climate, control/radio, control/travel, assistance features/office, and business features/ cellular telephone features/means for hanging up phone

- a cellular telephone installed in the upper section of the armrest of the centre console

- facsimile machine with a 1200 baud modem installed in the lower portion of the centre console armrest (area generally used for cassette tapes storage)

- thermal printer installed in the area normally housing the cassette tape player; any information shown on the reconfigurable display can be obtained, within the constraints of the 4-inch paper width, as a hard copy

- a compact disc system mounted above the printer; it provides mass data storage of information either carried on-board, transmitted to the vehicle, or for software programs specific to certain features

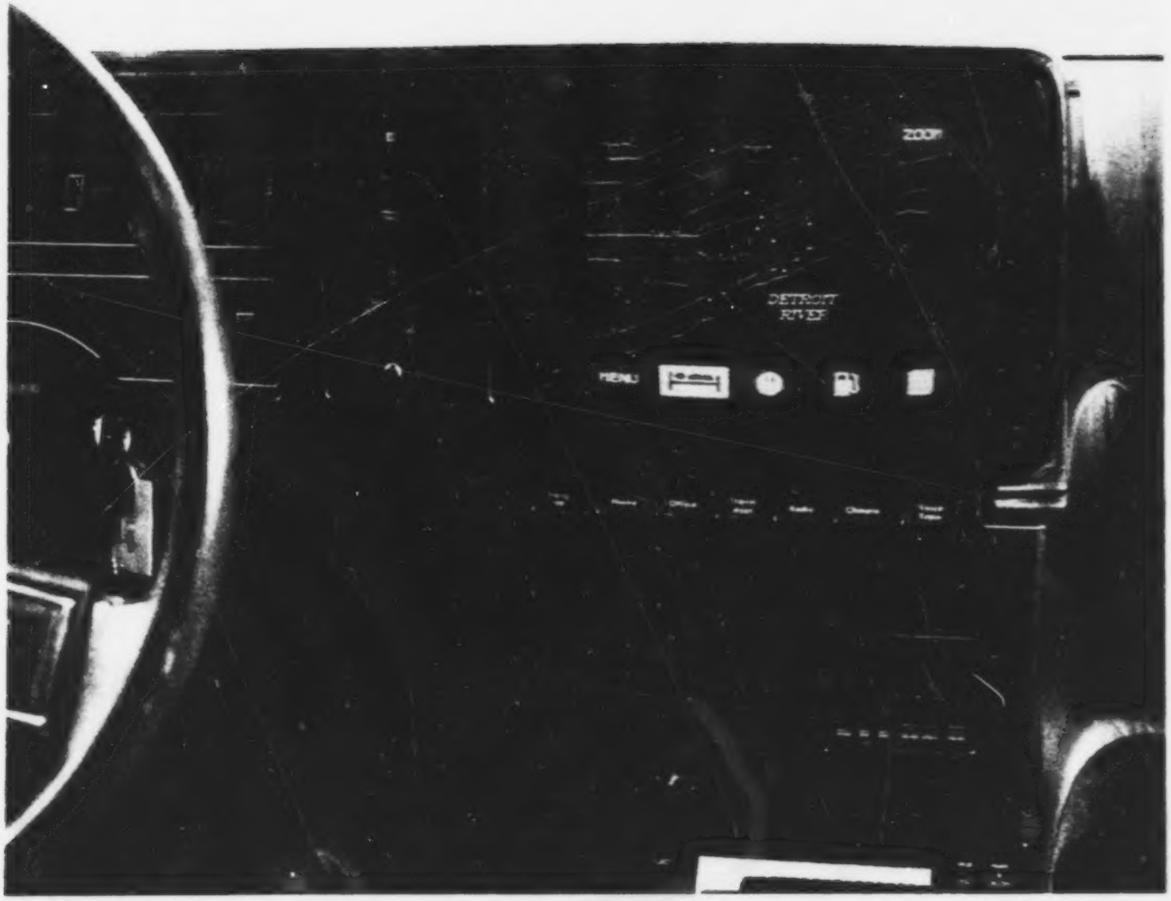
- microphone centred above the windshield to provide speaker dependant voice recognition capability; using "wake up" switches located beneath each steering wheel spoke, the system can be voice commanded to provide any of the operations possible through use of the switches

Some of the features (functional capabilities), all of which are not operational when the vehicle is moving, are:

- for dialing: names/phone numbers can be entered to 3 speed dial pages from the compact disk, through a communication link or through manual entries by the driver; once entered, the person can be dialed by touching the reconfigurable "soft"

EXHIBIT 37

GM MOBILE INFORMATION SYSTEM


ZOOM
DETROIT RIVER
MENU
Phone
Office
Radio
Climate

switch bearing his/her name; soft switches at the bottom of the display permit access to a telephone keypad or to a directory (e.g., Toronto)

- for business traveller: electronic calendar similar to current office versions (and a host of features using the CD content); reception and storage of phone messages, calendar updates, etc from an external secretarial service to be displayed upon request by the driver; the driver can return the call through use of a phone icon, determine the location of the caller with a map icon, or decide to put off action until later

- travel assist: contains options for navigation assistance, landmarks or destination assistance, travel advisories and route selection

- navigation -> a dead-reckoning/map-matching system tracks and displays location of the vehicle; destinations can be located using built-in geocoding feature; several zoom levels and pan are available

- destination assistance -> displays a map with landmarks, lodgings, restaurants, vehicle services; a listing can be obtained through the icons at the bottom of the screen; other menu items provide amenities, hours of operation, rates

- touching phone icon, places a call to that facility

- touching map icon will return to previous map where that facility is now displayed with a blinking dot

- combining destination and navigation features would display the vehicle and destination on the same map (depending on scales) to help in route selection

The combined navigation/destination assistance features could operate entirely with static information – street networks, landmarks, etc. – brought to the vehicle on a CD. A critical capability while no smart road system features are offered (although the CD content would need to be periodically updated). Considerable increase in service would be provided if dynamic (traffic, weather, parking lot status, etc.) information were collected and transmitted to the vehicle via a one-way communication link (road side beacons, wide area broadcasts). A two-way link would allow the vehicle to "return the favour" to the system by providing information on its progress through the network (i.e., level of congestion).

- traffic advisory: presents the driver with a map showing levels of congestion on each facility (that is monitored in real time); routing options left to the driver

- route selection: provides an optimized route to selected destination – that could be based, depending on content of the data base, on least time (circumventing a heavily congested section), least distance, most use of freeways, fewest left turns at intersections, etc.

In presenting this system, Daniel L Frank of G.M. summarizes the near-term future as follows:

> *"Automotive manufacturers will not build 'smart' vehicles if there are no 'smart' roads on which to operate them. 'Smart' roads will not be built if there are no 'smart' cars to take advantage of their capabilities. The motoring public will not purchase the feature sets until a support infrastructure exists and the infrastructure will not appear until a sufficient customer base and revenue stream is envisioned. For these reasons, the first implementations will provide highly autonomous vehicles, using whatever static and dynamic information is available to them. As demonstration programs indicate incentives, products and business opportunities for travel assistance features, support infrastructures will develop and the vehicles will become relatively less smart, relying more heavily on dynamic information and services provided by infrastructure."*

4.3.2 Bosch Board Information Terminal

Bosch-Blaupunkt define the objectives/features for their experimental travel support system, called BOSCH BIT (Board Information Terminal), as follows:
- safety -> parking assistance, external information
- reliability -> check-control, on-board diagnosis
- comfort -> radio, mobile telephone, navigation system, air conditioning, smart actuators, trip computer.

Inputs are handled through a touch panel or voice, the outputs are provided through display unit (76 x 103 mm LCD, 9 lines x 24 char.), warning lights, audible alarm, voice, and touch-sensitive systems. BIT unites many separate systems and integrates them with a central control system for the car. [Exhibits 38 (picture), 39 (groups), 40 a and 40 b (box-diagrams)]

Another BIT-related development is a concealed, four-sensor, phased-array, Auto Directional Antenna system which has no moving parts. The "antenna" is derived from the signals picked up by four concealed, bumper-mounted foil sensor units (eliminating the need for traditional whip or window-foil antennas). The radio waves reach each bumper unit at a different time and with a different relative phase. By phased-array processing – originally developed for military space tracking radars – of these signals, the derived "antenna" can be electronically 'rotated' to seek for the best signal

EXHIBIT 38

BOARD INFORMATION TERMINAL DEMONSTRATION UNIT

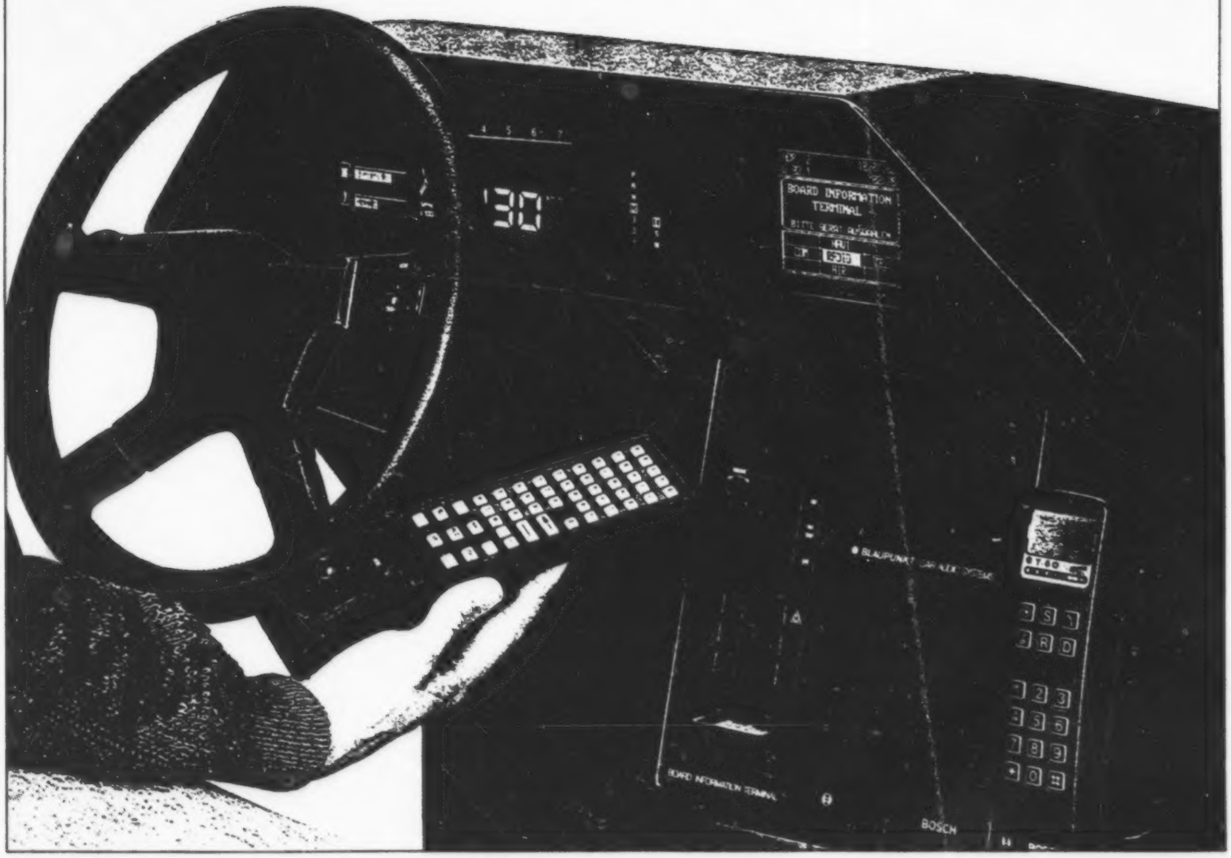

30
BOARD INFORMATION TERMINAL
BLAUPUNKT CAR AUDIO SYSTEMS
BOARD INFORMATION TERMINAL
BOSCH

EXHIBIT 39

BIT FUNCTIONAL GROUPINGS

AUDIO SYSTEM

* car radio (modular)
* high freq tuner with audio directional antenna (ADA)
* storage media (CC, CD, DAT)
* CD changer
* parametric sound amplifier (PSA)

VIDEO SYSTEM

* TV receiver
* videotex decoder
* video recorder
* video camera

COMMUNICATION SYSTEMS

* telephone (mobile/portable)
* cellular broadcasting (CB)
* data interface for post/mail service: telefax teletex btx
* handsfree equipment
* personal computer (PC)
* paging decoder
* data transfer

VEHICLE COMMUNICATION SYSTEM (PROMETHEUS)

* car-to-car communication
    - signals from vehicle&sensor data
    - adjustments of car maneuvers
* vehicle infrastructure communication
    - traffic info system
    - alarm systems

NAVIGATION SYSTEMS

* orientation/location system
* guidance system

VOICE SYSTEM

* voice storage
* voice output
* voice input

ON-BOARD SYSTEMS

* trip computer
* clock
* timer
* special heating systems (seat, outside mirrors, rear window)
* check of electronic control units (ABS/ASC, engine mgt, electronic suspension, etc)
* on-board diagnosis
* smart card unit
* air-conditioning
* smart actuators (seat, seat belt, mirror, steering wheel, etc)
* check of sensor systems (fuel, oil, water, tire pressure, lights, etc)

SURVEILLANCE SYSTEM FOR THE IMMEDIATE AREA

* reverse driving support
* blind spot sensor
* close range sensor
* IR sight help

SAFETY SYSTEM

* alarm installation
* theft protection
* central locks

EXHIBIT 40a

BOARD INFORMATION TERMINAL

* Communication Systems *

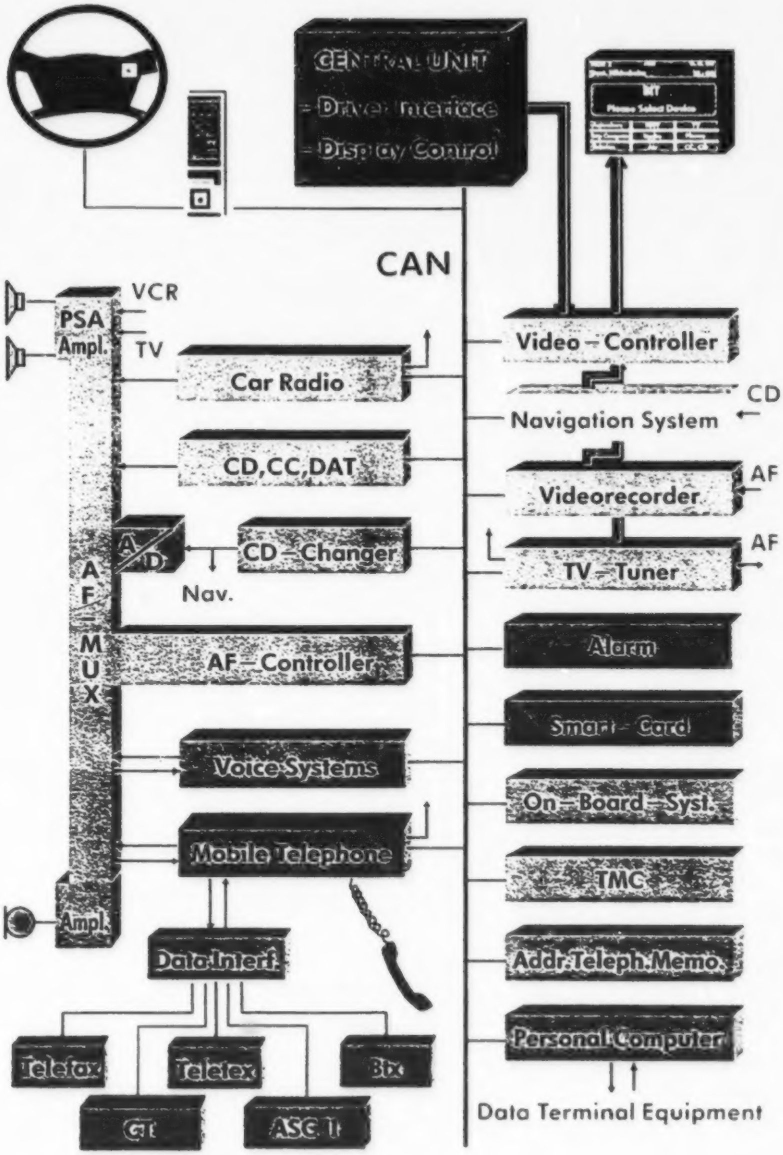
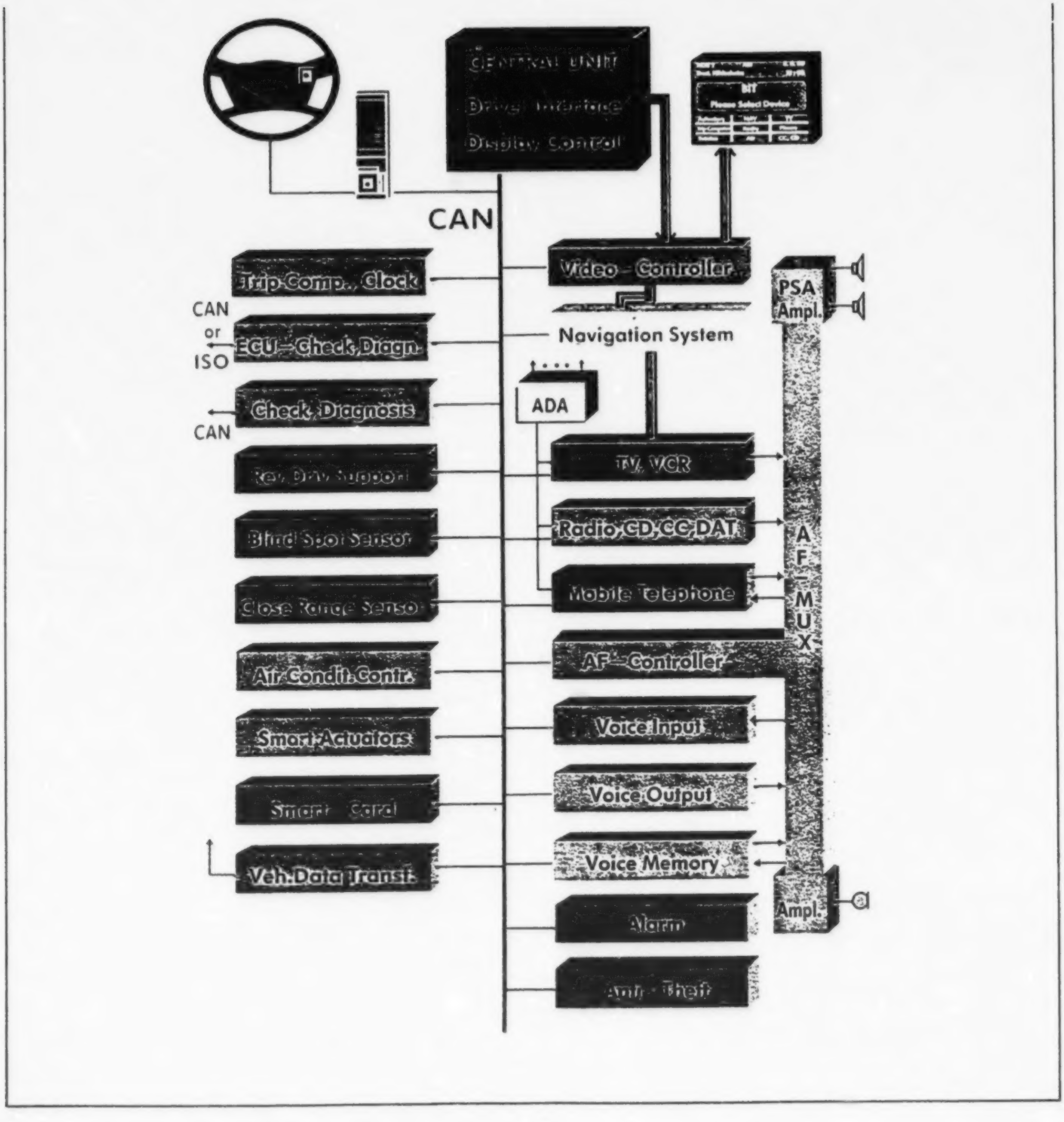

CENTRAL UNIT
- Driver Interface
- Display Control
Please Select Device
CAN
VCR
PSA Ampl.
TV
Car Radio
CD,CC,DAT
A/D
CD – Changer
Nav.
A F – M U X
AF – Controller
Voice Systems
Mobile Telephone
Ampl.
Data Interf.
Telefax
Teletex
Btx
GT
ASC II
Video – Controller
CD
Navigation System
Videorecorder
AF
TV – Tuner
AF
Alarm
Smart – Card
On – Board – Syst.
TMC
Addr. Teleph. Memo.
Personal Computer
Data Terminal Equipment

EXHIBIT 40b

BOARD INFORMATION TERMINAL

* On-Board Systems *


CENTRAL UNIT
Driver Interface
Display Control
BIT
Please Select Device
CAN
Trip Comp., Clock
CAN
or
ISO
ECU – Check Diagn.
Check Diagnosis
CAN
Rev. Driv. Support
Blind Spot Sensor
Close Range Sensor
Air Condit. Contr.
Smart Actuators
Smart Card
Veh. Data Transf.
Video – Controller
Navigation System
ADA
TV, VCR
Radio, CD, CC, DAT
Mobile Telephone
AF – Controller
Voice Input
Voice Output
Voice Memory
Alarm
Anti – Theft
PSA
Ampl.
AF – MUX
Ampl.

and reject unwanted signals – that is, to reject multipath distortion caused by radio waves having been bounced of mountains, buildings and other objects. The ADA's phased-array processor varies the relative phase of the signals so they can be added together in-phase. Only signals coming in from one direction can be added in this manner; signals arriving from other directions will tend to be cancelled out.

This method should not be confused with less sophisticated diversity reception systems that simply compare signals from two or more antennas and switch to the best signal; such systems are not directional and the switching can be audible. In ADA, the signal-monitoring computer responds to changing conditions within milliseconds, so the changes in reception parameters are totally inaudible to the listener.

4.3.3 Implications

The Mobile Information Systems Impact Study summary states:

> *"Safety-in-use will have to be the primary consideration in the development of mobile information systems, and much work is yet to be done on the design, installation and use of these systems. Research should be undertaken to determine the amount of information that can be safely presented to the driver when the vehicle is in motion – depending on whether the driver is in a familiar or unfamiliar are, what the road and traffic conditions are etc. Sound research is essential to ensure that these devices will enhance, rather than degrade, the overall safety of the driver/vehicle/road system."*

The MISIS report also contains recommendations for preliminary design guidelines (Section 6.3.2/p164-166) and for specific human factors studies and demonstration projects that ought to have been initiated. These study proposals should be further refined in light of the human factors discussion presented in this report (Chapter 3).

5 INTERNATIONAL PROGRAMS

A description of the national programs in Europe, Japan and North America is contained in the final report of the Mobile Information Systems Impact Study [1, p.122-154]. Brief summaries of these programs, updates on their status and some additional specifics on their interrelationships are presented in the following.

5.1 Europe

5.1.1 DRIVE

DRIVE – Dedicated Road Infrastructure for Vehicle Safety in Europe - is a program of the Commission of the European Communities (CEC). DRIVE is aimed at research and development work in the field of Road Transport Informatics (RTI). The program is managed and coordinated by Directorate General XIII (Telecommunications, Information Industries and Innovation) of CEC.

DRIVE has three primary objectives:
1. improving road safety
2. maximizing of and breakthrough in road transport efficiency
3. contributing to environmental improvements.

DRIVE is defined by a workplan. The workplan formed the basis for the call for proposals, published in the official Journal of the European Communities on July 2, 1988. In response to the call, 189 proposals representing about 500 man-years of work were received. The proposals included some 650 manufacturers, universities, research institutes, and other organizations with a total of 950 participants. The total DRIVE budget is around U.S. $160 M.

The management of the DRIVE program is divided as follows:

- individual project management is the responsibility of the prime contractor of each DRIVE project

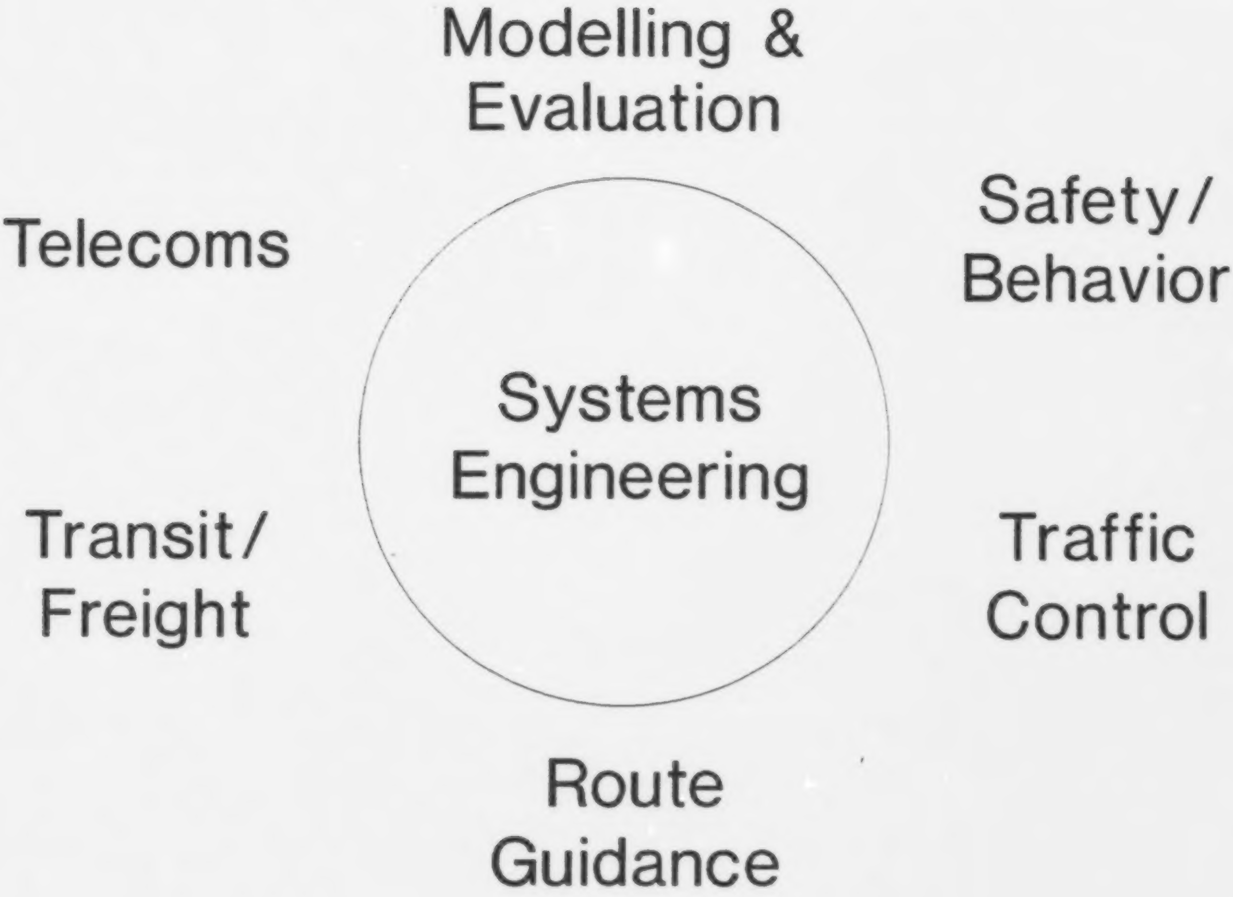
- overall program management is the responsibility of the European Commission Directorate

- consensus formation efforts are the responsibility of the System Engineering and Consensus Formation Office (SECFO).

The DRIVE program has been divided into seven different work areas (illustrated in Exhibit 41):

EXHIBIT 41

DRIVE PROJECT AREAS



Modelling & Evaluation

Telecoms

Safety/ Behavior

Systems Engineering

Transit/ Freight

Traffic Control

Route Guidance

1. Evaluation and Modelling – To achieve the goal of optimizing Road Transport Informatics (RTI) in Europe, the DRIVE program is supporting the development of suitable techniques to simulate and evaluate the effects of RTI implementation. The following projects are included in this area:

   - pollution reduction by traffic information and control techniques
   - building a dynamic traffic model for testing RTI applications in small urban areas
   - development of a tool for traffic forecasting and transportation planning
   - driver behaviour in response to a range of possible RTI scenarios
   - building an integrated model appropriate for RTI policy analysis
   - recommendations and specifications for field trials of RTI applications.

2. Behavioural Aspects & Traffic Safety – Improved highway safety is anticipated as a primary outcome of the DRIVE program. DRIVE projects in this work area include:

   - development of an automatic policing system
   - design standards for intelligent co-driver systems
   - feasibility study on the monitoring of driver status
   - assessment of factors in elderly people's driving abilities
   - assessment of changes in driver behaviour due to the introduction of RTI technologies
   - production of standards for in-vehicle man machine interface
   - definition of techniques for presenting information to drivers.

3. Traffic Control – work area includes the following projects:

   - development of strategies for an integrated demand management system
   - development of an artificial intelligence based system for traffic control
   - development of a real time urban traffic control system
   - integration of computer vision techniques for automatic incident detection
   - development of an integrated tunnel control system
   - survey of potential applications of artificial intelligence to solve traffic engineering problems
   - development of techniques for obtaining real-time origin and destination information
   - development of road condition and weather monitoring systems.

4. Route Guidance, Vehicle Location, Maps and In-Vehicle Information – systems are key concepts in RTI. The following projects are included in this work area:

   - development of a vehicle location system using satellites

- development of a prototype digital road network database
- integration of dynamic route guidance and traffic control
- development of standards for the Radio Data System / Traffic Message Channel (RDS/TMC) throughout Europe.

5. Public Transit and Freight Management – work area includes the following projects:

   - development of a transit vehicle scheduling and control system
   - development of systems for freight and commercial fleet management.

6. Telecommunication - work area includes the following projects:

   - determine the potential of microwaves for RTI applications
   - develop an RTI system based on cellular radio
   - perform a comparative evaluation of different radiating cables and system technologies
   - standardize traffic data transmission and data management
   - develop data acquisition and communication techniques.

7. Consensus Formation – The overall objectives of the consensus projects are:

   - prepare common functional specifications for international standardization bodies and establish common practices for the development and implementation of RTI, based upon the results of the DRIVE projects
   - interpret user requirements with respect to the technical and systems engineering work in DRIVE, based on the results of the projects.

5.1.2 EUREKA

EUREKA is a $5 billion European research program which seeks to enhance the competitiveness of European enterprises worldwide and aid these enterprises in commercializing high technology products and services. The program was initiated in 1985. At present, there are 19 European countries participating in the program and over 400 European firms and organizations. The project is subdivided into five major programs and two supporting programs. The 5 major programs (a-e), the two supporting projects (f and g) and their budgets are as follows:

a) PROMETHEUS	327	M ECU
b) EUROPOLIS	128	
c) CARMINAT	52	
d) ATIS	7	

e) ERTIS	2	
f) DAB	38	M ECU
g) DEMETER	5	
Total	559	M ECU (approx. $680M US)

Following is a brief description of these programs:

a) PROMETHEUS

PROMETHEUS – **PRO**gra**M** for a **E**uropean **T**raffic with **H**ighest **E**fficiency and **U**nprecedented **S**afety – is a European research program which has the objective of developing concepts and solutions for increasing road traffic safety, efficiency and economy while reducing vehicle-born pollution. Since October 1986, over 300 scientists and engineers from five European countries have been jointly working on this program. The common objectives of PROMETHEUS are to:

- improve the competitiveness of European industry
- improve highway transportation in all its aspects
- stimulate European basic and applied research and technology in general.

The strategy for achieving these objectives is as follows:

- cooperative action, involving the automobile industry, supply and electronics industries, the state and scientific community

- pan-European cooperation in research, system development, and solution implementation.

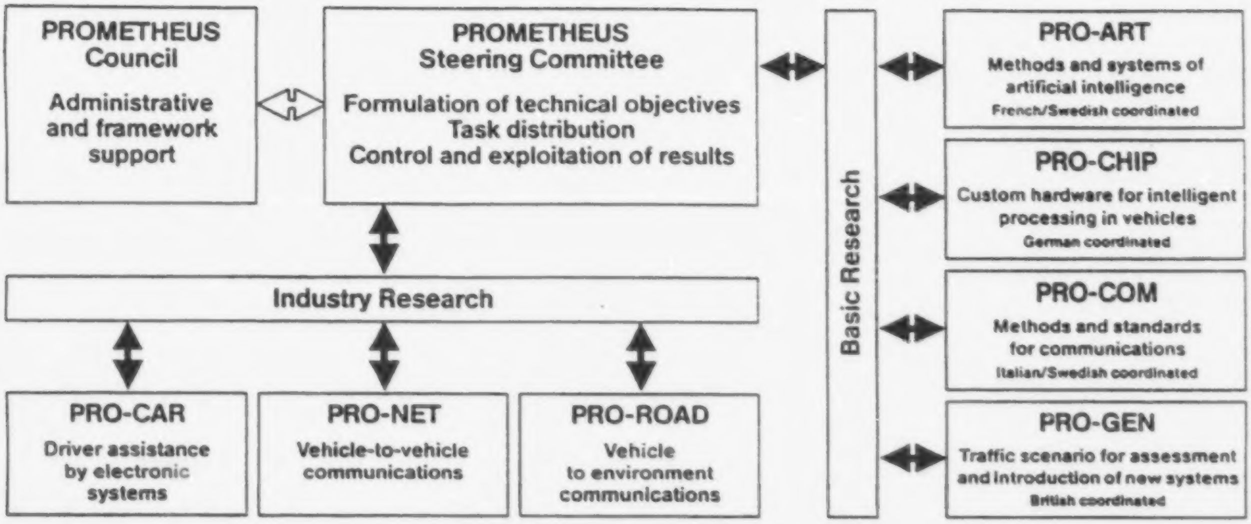
PROMETHEUS is divided into three industrial sub-programs, and four basic research sub-programs (illustrated in Exhibit 42):

Industrial research

PRO-CAR:	development of driver-assisting electronic systems
PRO-NET:	development of systems for vehicle-to-vehicle communication
PRO-ROAD:	development of communication and information systems between roadside and on-board equipment.

EXHIBIT 42

PROMETHEUS ORGANIZATION


PROMETHEUS Council
Administrative and framework support
PROMETHEUS Steering Committee
Formulation of technical objectives
Task distribution
Control and exploitation of results
Industry Research
PRO-CAR
Driver assistance by electronic systems
PRO-NET
Vehicle-to-vehicle communications
PRO-ROAD
Vehicle to environment communications
Basic Research
PRO-ART
Methods and systems of artificial intelligence
French/Swedish coordinated
PRO-CHIP
Custom hardware for intelligent processing in vehicles
German coordinated
PRO-COM
Methods and standards for communications
Italian/Swedish coordinated
PRO-GEN
Traffic scenario for assessment and introduction of new systems
British coordinated

basic research

PRO-ART: basic research into software and artificial intelligence methods
PRO-CHIP: basic research into micro electronics for vehicles and the highway
PRO-COM: system research into protocols and standards for mobile communications
PRO-GEN: system and basic research into scenarios for road transportation of the future.

b) EUROPOLIS

EUROPOLIS program is structured as follows:

- objective – automated highways after the year 2000
- participants – French, Spanish, Danish research groups
- duration – seven years.

c) CARMINAT

CARMINAT program is structured as follows:

- objective – to develop in-vehicle electronics, navigation and communication systems
- participants – Philips (CARIN) and Renault (ATLAS)
- duration – four years.

d) ATIS

Alliance Internationale de Tourisme Information System (ATIS) program is structured as follows:

- objective – provide pre-trip information on road traffic conditions and other subjects important to tourists
- participants – Swiss, Dutch and Austrian motorist/travel organizations
- duration – five years.

e) ERTIS

Electronic Road Transport Information System (ERTIS) program is structured as follows:

- objective – develop road information and communications systems for motor carriers.
- articipants – trucking firms and associations in Belgium, Denmark, the Netherlands and the United Kingdom

- duration – three years.

f) DAB

Digital Audio Broadcasting System program is structured as follows:

- objective – develop common standards for digital radio broadcasting
- participants – Philips, Bosch-Blaupunkt and seven other firms
- duration – five years.

g) DEMETER

Digital Electronic Mapping of European Territory (DEMETER) program is structured as follows:

- objective – advanced computer-aided cartography and development of common standards
- participants – Philips, Bosch-Blaupunkt
- duration – four years.

5.2 Japan

5.2.1 AMTICS

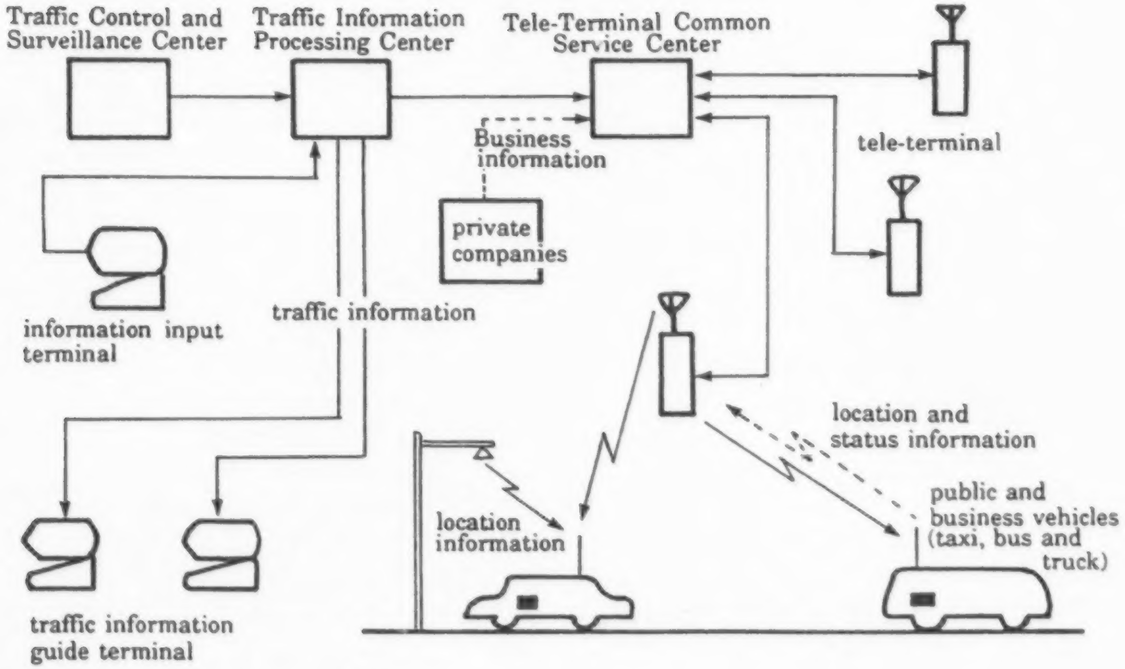
At the suggestion of the National Police Agency, the Japan Traffic Management Technology Association has set up a group to study – in cooperation with the Japanese Ministry of Posts and Telecommunications (MPT) and a number of private corporations – proposals for the Advanced Mobile Traffic Information & Communication System (AMTICS).

AMTICS is an integrated traffic information and navigation system. The system will display on-screen in each vehicle traffic information gathered at traffic control and surveillance centres managed by the police in 74 cities. Information on accidents, road repairs, and arbitrary traffic controls are input to the system manually, and then displayed on the traffic status display board.

The information is reprocessed by computer at the AMTICS data-processing centre and broadcast to vehicles. The broadcasting system being promoted by MPT is a new radio data communications system called teleterminal. The equipment in vehicle will consist of a display, a compact disk read-only memory (CD-ROM) reader for retrieving map information, and a microcomputer to calculate the vehicle's position and to superimpose it on the display. (see Exhibits 43a, 43b, 43c).

EXHIBIT 43a

AMTICS CONCEPT


Traffic Control and Surveillance Center
Traffic Information Processing Center
Tele-Terminal Common Service Center
Business information
private companies
tele-terminal
information input terminal
traffic information
traffic information guide terminal
location and status information
public and business vehicles (taxi, bus and truck)
location information

Source: Technological Innovations for Tomorrow's Automobile Traffic and Driving Information Systems, JSK International Symposium; p24, Nov 1989.

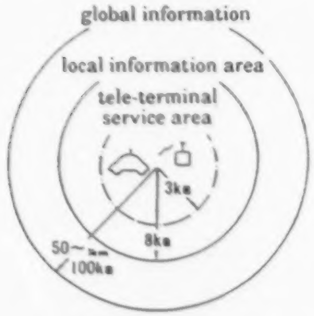
EXHIBIT 43b

AMTICS

- Information Provisions -

TYPE	INFORMATION	CATEGORY	PROVISION
DYNAMIC	congestion levels	basic	supplied through tele-terminal
	temporary traffic (road repairs, accidents, events, ice)		
	emergencies (warnings)		
	weather		
	parking lots		
	other (route guidance, ...)		
STATIC	road network data	service	supplied from storage media
	general traffic regulations (one-way, no right turns, ...)		
	parking lot locations		
	background data (railways, coast, rivers, admin boundaries, ...)		
	facilities location (hospitals, schools, ...)		
	gas station locations		
	sight seeing guide		
	residential map		
	other		

- Information Range -

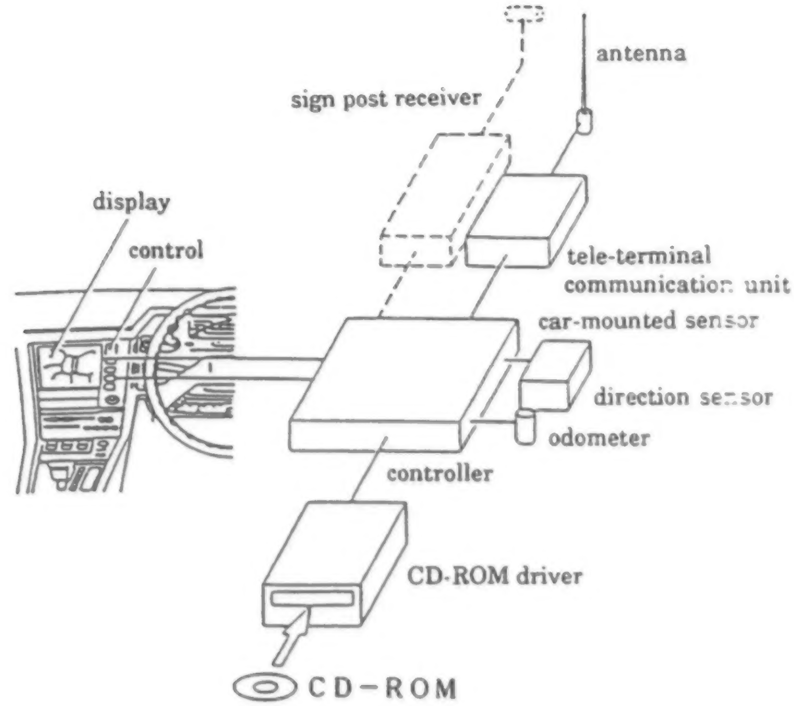

global information
local information area
tele-terminal service area
3km
8km
50~100km

Source: Technological Innovations for Tomorrow's Automobile Traffic and Driving Information Systems, JSK International Symposium; p25, Nov 1989.

EXHIBIT 43c

AMTICS

- Typical Car-Mounted Unit -


antenna
sign post receiver
display
control
tele-terminal communication unit
car-mounted sensor
direction sensor
odometer
controller
CD-ROM driver
CD-ROM

Source: Technological Innovations for Tomorrow's Automobile Traffic and Driving Information Systems, JSK International Symposium; p26, Nov 1989.

The major benefit of this system will be its ability to display in real-time not only the vehicle's current position and route, but also information on traffic congestion, regulation, highway maintenance and parking. The system is also being considered for application to business vehicle management systems.

On April 27, 1987, after the AMTICS research group issued its report, a Conference on the Practicability of AMTICS was organized with the participation of 59 private corporations. Twelve groups of companies have joined together to develop elements of the system within an overall coordinated framework. An experimental system was started in Tokyo in 1988 and the first commercial system will be available in Tokyo and Osaka in 1990. Out of 12 000 traffic signals in Tokyo, 6000 have been integrated into the system.

5.2.2 RACS

The Public Works Research Institute has been engaged in the development of RACS - Road/Automobile Communication System – since 1986 as a joint development project with 25 private corporations. It is composed of communication devices (beacons) installed along roads, the in-vehicle units, and a central processing system (control centre). Communication between the in-vehicle unit and the beacon is via radio link; the beacons are linked to the system centre via communication cable networks. (For general concept, see Exhibit 44a.)

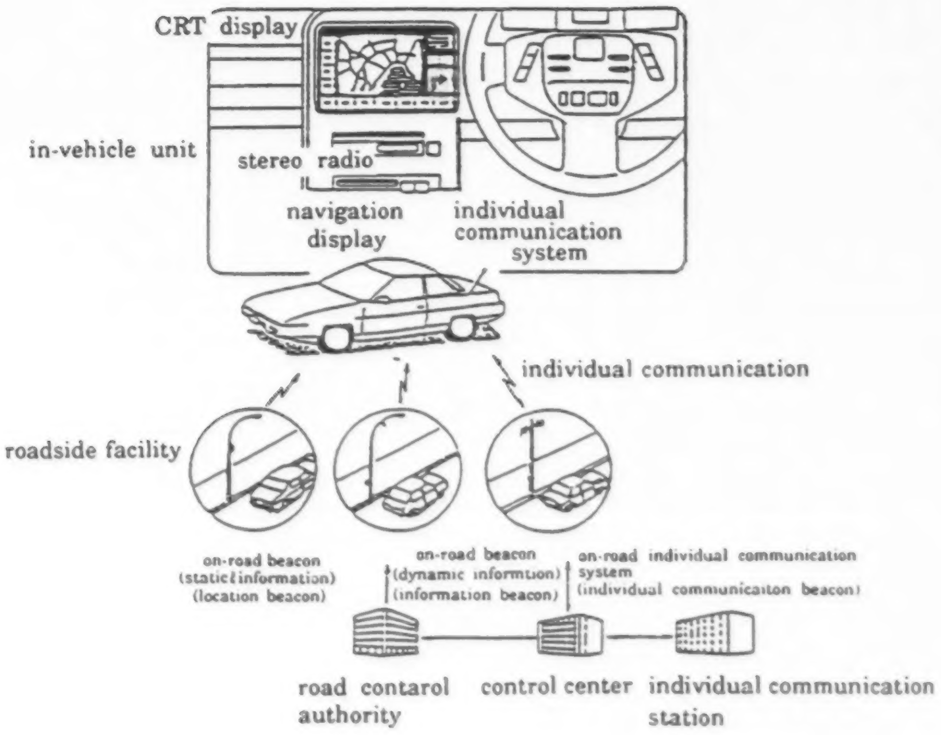
System functions vary with the stage of development of the system, but will be developed in the following three stages:

- navigation function: vehicle position and route guidance; correction of cumulative location errors through beacon signals
- information service: traffic and parking
- individual communication function: between cars.

For the intermittent burst communication option, i.e., spot radio communication around each beacon, the technical features and system features are presented in Exhibit 44b. A comprehensive system test is underway – to verify that the navigation, information supply and individual communication services function properly using sub-microwave bands. The test facility and equipment are presented in Exhibit 44c.

EXHIBIT 44a

RACS CONCEPT

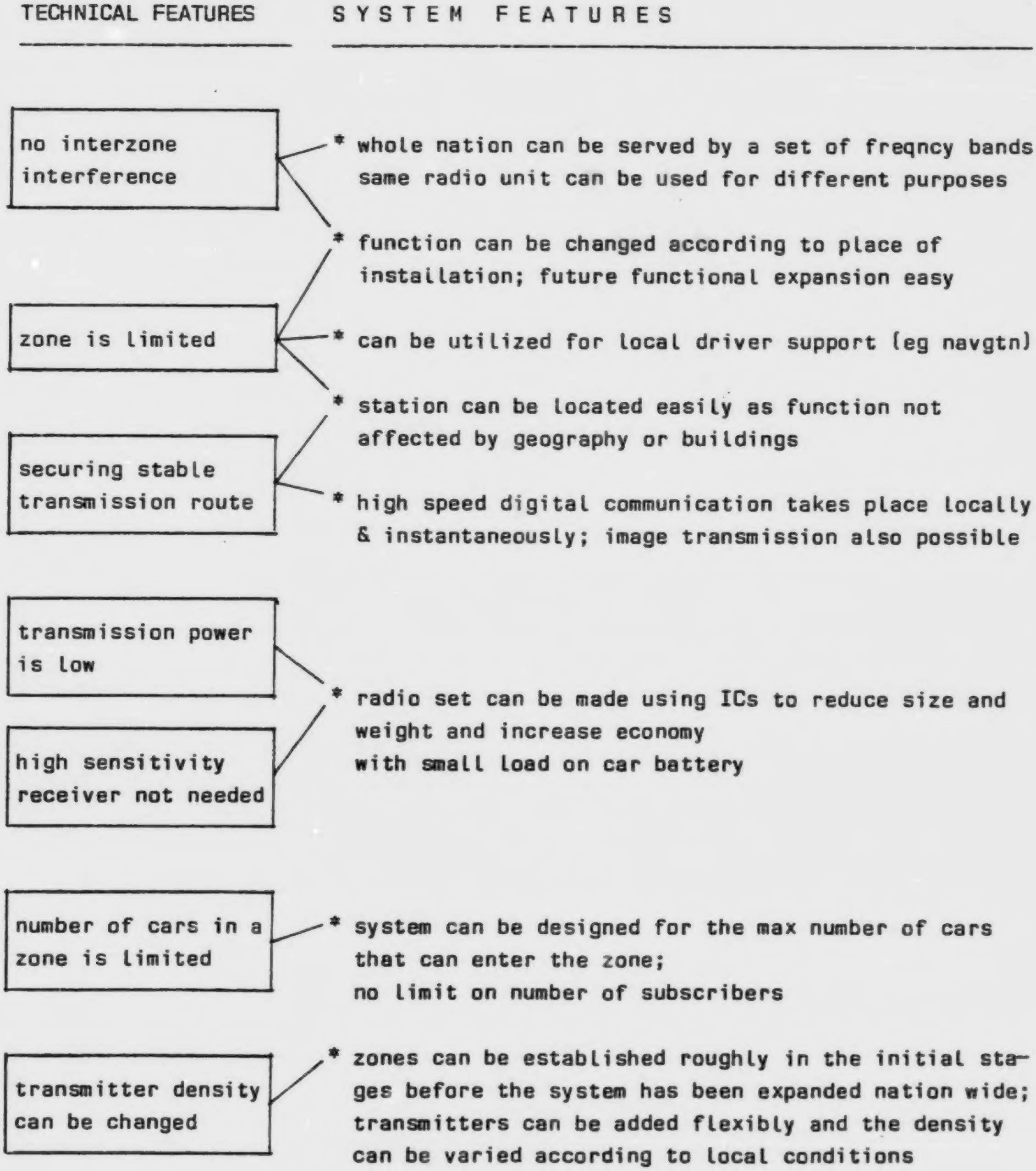

CRT display
in-vehicle unit
stereo radio
navigation display
individual communication system
individual communication
roadside facility
on-road beacon
(static&information)
(location beacon)
on-road beacon
(dynamic informtion)
(information beacon)
on-road individual communication system
(individual communicaiton beacon)
road contarol authority
control center
individual communication station

Source: Technological Innovations for Tomorrow's Automobile Traffic and Driving Information Systems, JSK International Symposium; p32, Nov 1989.

EXHIBIT 44b

RACS

- Features of an Intermittent, Minimum Zone System -



TECHNICAL FEATURES

SYSTEM FEATURES

no interzone interference

* whole nation can be served by a set of freqncy bands same radio unit can be used for different purposes

* function can be changed according to place of installation; future functional expansion easy

zone is limited

* can be utilized for local driver support (eg navgtn)

* station can be located easily as function not affected by geography or buildings

securing stable transmission route

* high speed digital communication takes place locally & instantaneously; image transmission also possible

transmission power is low

* radio set can be made using ICs to reduce size and weight and increase economy with small load on car battery

high sensitivity receiver not needed

number of cars in a zone is limited

* system can be designed for the max number of cars that can enter the zone; no limit on number of subscribers

transmitter density can be changed

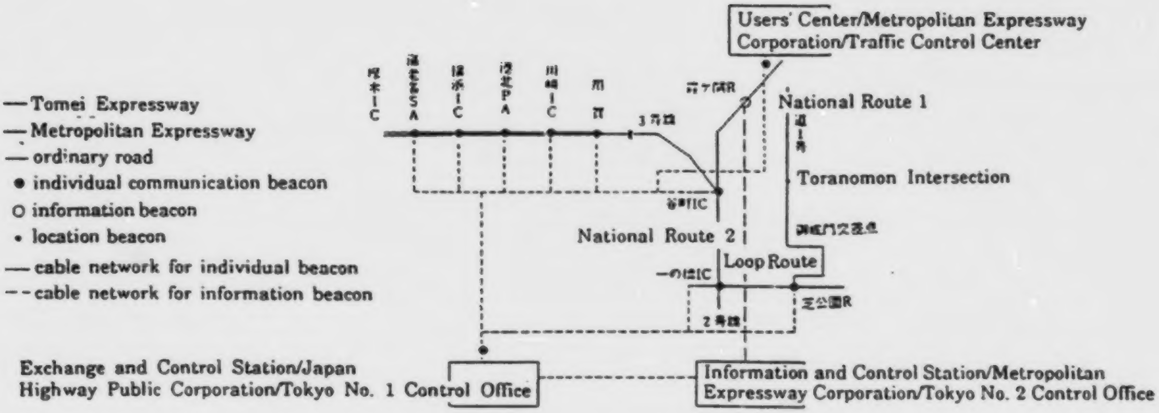
* zones can be established roughly in the initial stages before the system has been expanded nation wide; transmitters can be added flexibly and the density can be varied according to local conditions

Source: Technological Innovations for Tomorrow's Automobile Traffic and Driving Information Systems, JSK International Symposium; p33, Nov 1989.

EXHIBIT 44c

RACS

- Facilities Used in Comprehensive System Test -


Users' Center/Metropolitan Expressway Corporation/Traffic Control Center
— Tomei Expressway
— Metropolitan Expressway
— ordinary road
● individual communication beacon
○ information beacon
• location beacon
— cable network for individual beacon
-- cable network for information beacon
厚木IC
海老名SA
横浜IC
港北PA
川崎IC
用賀
3号線
霞ケ関R
National Route 1
国道1号
Toranomon Intersection
谷町IC
虎ノ門交差点
National Route 2
Loop Route
一の橋IC
芝公園R
2号線
Exchange and Control Station/Japan Highway Public Corporation/Tokyo No. 1 Control Office
Information and Control Station/Metropolitan Expressway Corporation/Tokyo No. 2 Control Office

Source: Technological Innovations for Tomorrow's Automobile Traffic and Driving Information Systems, JSK International Symposium; p36, Nov 1989.

5.3 North America

5.3.1 HELP

The Heavy Vehicle Electronic License Plate (HELP) program concept was devised as a means of providing a system for heavy vehicle management. The HELP system will automatically weigh, classify and identify heavy vehicles at strategic locations on the highway. The resultant data can be stored, processed and retrieved in such a way as to provide both government and the trucking industry with useful, consistent data for many purposes.

The basic notion of an integrated HELP system was first discussed by Arizona and Oregon Departments of Transportation in 1983, leading to the production of two concept papers. Soon it became apparent that there was support for the system concept from various other states and from the Federal Highway Administration (FHWA). The FHWA provided grants to Arizona DOT to undertake a feasibility study and to Oregon DOT to perform a proof-of-concept demonstration.

The initial feasibility study was concluded in December 1984 and gave encouraging results. These were confirmed by the Oregon concept demonstration. The system concept was found to be technically feasible, potentially offering benefits to states and truckers alike. A multi-state development and testing program was outlined which would bring this concept to reality.

The states currently participating in the HELP program are Arizona, California, Idaho, Iowa, Minnesota, Nevada, New Mexico, Oregon, Pennsylvania, Texas, Virginia, Washington and the Canadian province of British Columbia – as well as the Port Authority of New York and New Jersey. The U.S. federal government is represented by the Federal Highway Administration and the Canadian federal government by the Transportation Development Centre of Transport Canada.

The HELP program structure is illustrated in Exhibit 45a. The following studies comprise the technical research and development phase:

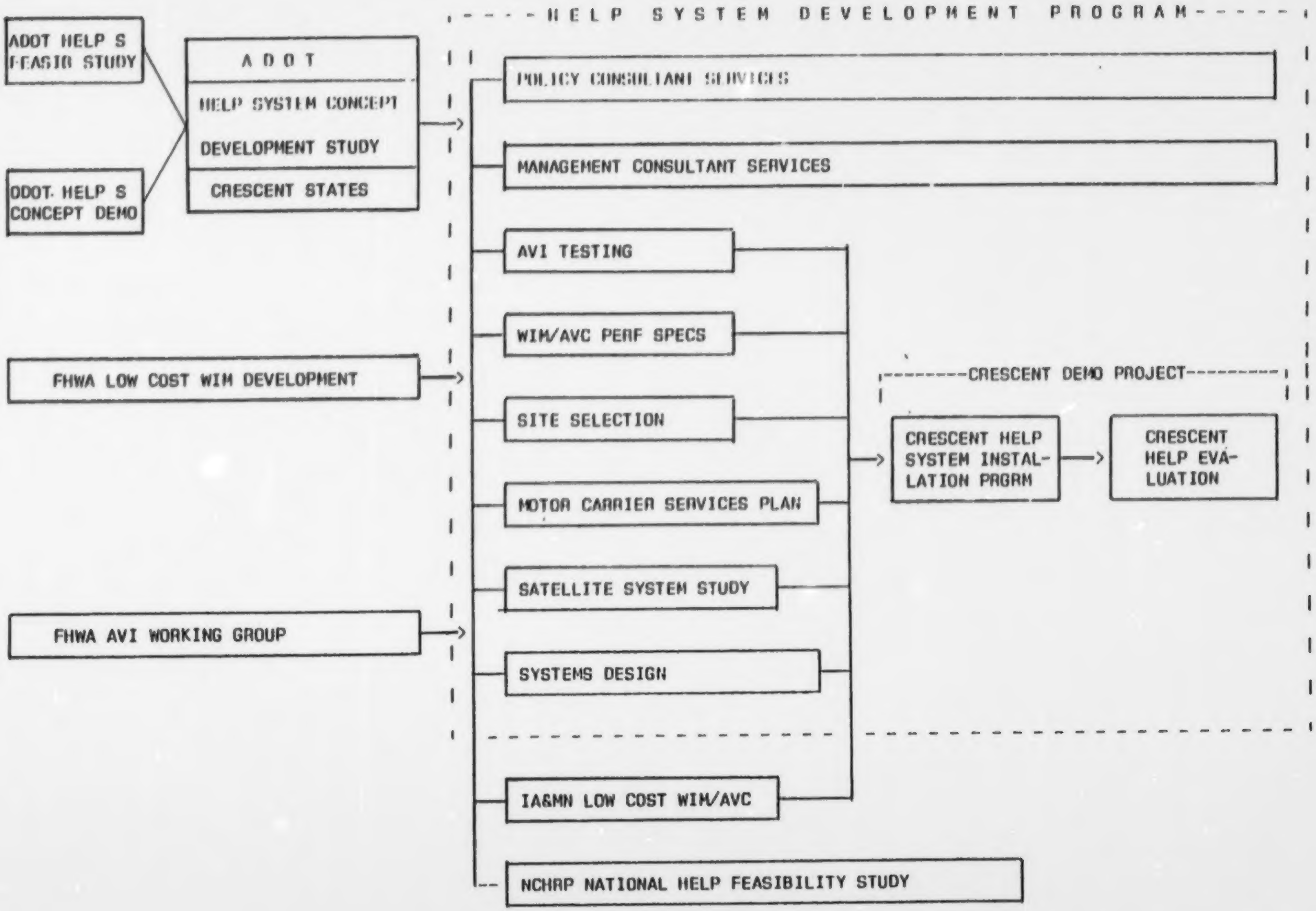
1. Development of AVI Specification

- Objective: to test existing commercial AVI systems and to develop an open, generic specification meeting the specific requirements of the HELP program.

- Other participants:
  - Arizona DOT – track testing

EXHIBIT 45a

HELP SYSTEM DEVELOPMENT PROGRAM


ADOT HELP S FEASIB STUDY
ODOT. HELP S CONCEPT DEMO
A D O T
HELP SYSTEM CONCEPT
DEVELOPMENT STUDY
CRESCENT STATES
FHWA LOW COST WIM DEVELOPMENT
FHWA AVI WORKING GROUP
HELP SYSTEM DEVELOPMENT PROGRAM
POLICY CONSULTANT SERVICES
MANAGEMENT CONSULTANT SERVICES
AVI TESTING
WIM/AVC PERF SPECS
SITE SELECTION
MOTOR CARRIER SERVICES PLAN
SATELLITE SYSTEM STUDY
SYSTEMS DESIGN
CRESCENT DEMO PROJECT
CRESCENT HELP SYSTEM INSTAL-LATION PRGRM
CRESCENT HELP EVA-LUATION
IA&MN LOW COST WIM/AVC
NCHRP NATIONAL HELP FEASIBILITY STUDY

  - CALTRANS – laboratory testing
  - Oregon State University/Oregon DOT – field testing

  - Virginia DOT – preferred system field testing
  - Vapor Canada/Austec Electronic Systems – preferred system manufacturer

- Duration: 1986-1989

2. Development of WIM Performance Specs

- Objective: to test existing commercial WIM systems through laboratory and field tests and develop a performance specification for HELP requirements.

- Contractor: Texas Transportation Institute

- Other participants:
  - Oregon DOT – field testing
  - Idaho DOT – field testing
  - Illinois DOT – field testing

- Duration: 1986-1989

3. Satellite Reference System Design Study

- Objective: to assess the feasibility of using satellite communications for vehicle monitoring in the HELP system.

- Contractor: Ernst and Whinney

- Duration: July 1986 - September 1987

4. System Design Study

- Objective: to review the approaches to the design of a computerized communication system for the HELP program and to investigate issues of data privacy and management options.

- Contractor: Cimarron Software Services

- Other participants: Sydec Inc

- Duration: April 1986 - June 1987.

5. On-board Computer Study

- Objective: to review on-board computer technology and motor carrier auditing requirements of states and to recommend an OBC-log format satisfying state requirements.

- Contractor: Arthur Andersen Consulting

- Duration: December 1988 – March 1989

Planning is currently underway for a multi-state demonstration and evaluation project, known as the Crescent Project. This will involve installation of the fully developed system in a group of western states. As currently configured there are 37 crescent installation sites planned throughout the six states of Washington, Oregon, California, Arizona, New Mexico and Texas along Interstate 5 and 10 (Exhibit 45b). The Crescent route will also extend into British Columbia, where there will be two sites: Pacific Site (#99 northbound) and Laidlaw Site (Trans Canada Highway eastbound). The Canadian participation also involves the provision of WIM/AVI equipment (for Canadian sample specifications, see Appendix G).

Fifteen potential applications have been developed for the Crescent demonstration. These can be divided into the following categories:
- data collection
- enforcement
- vehicle management

The specific applications are illustrated in Exhibit 45c and are summarized below:

- State data collection
  - dynamic truck gross weights and axle weights
  - classified vehicle counts
  - truck location, date and time for AVI equipped vehicles

- Weight enforcement
  - fixed site weight screening
  - pre-clear for registration, operating authority, weights, dimensions and safety inspection.

EXHIBIT 45b

PLANNED CRESCENT INSTALLATIONS

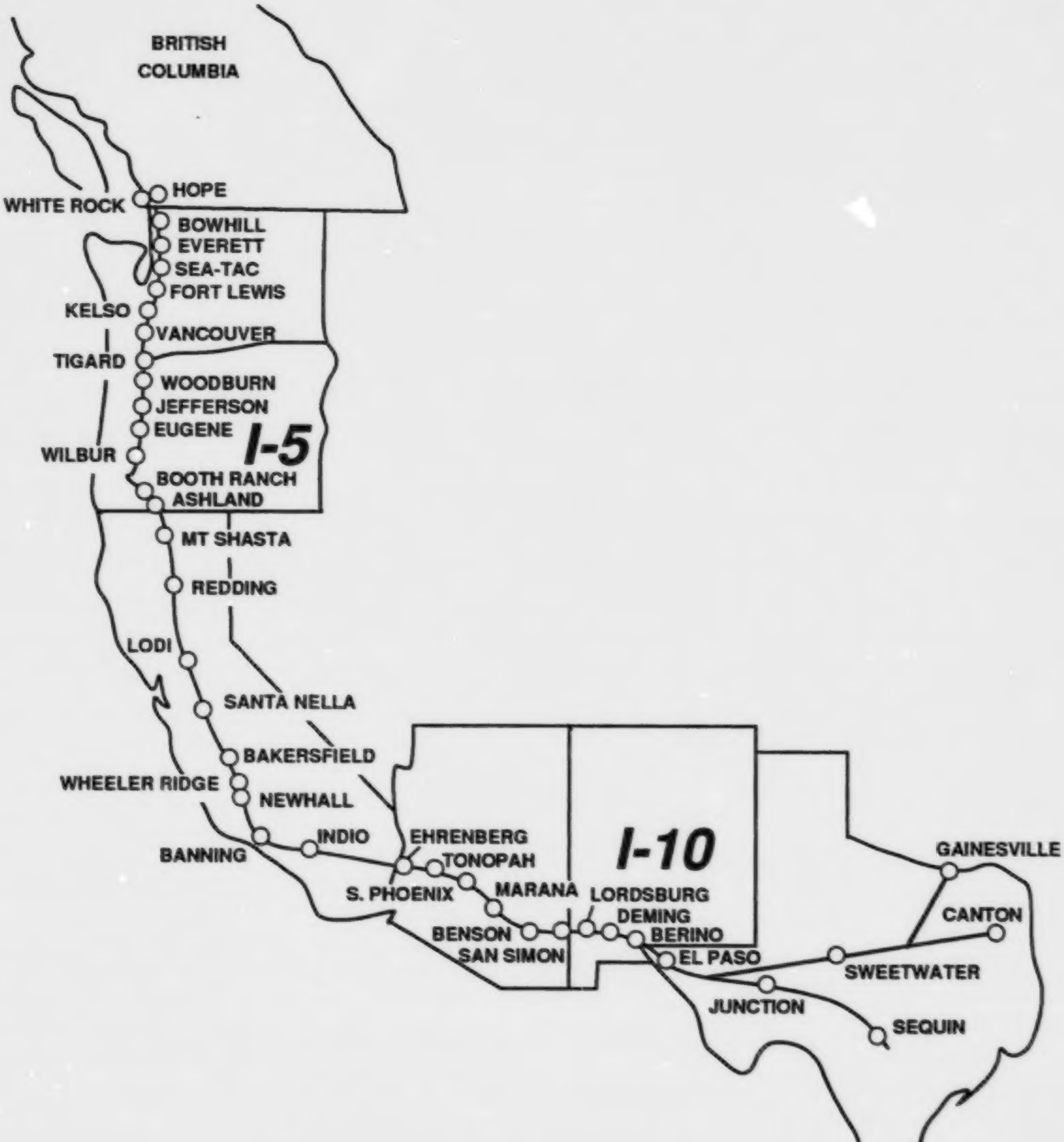
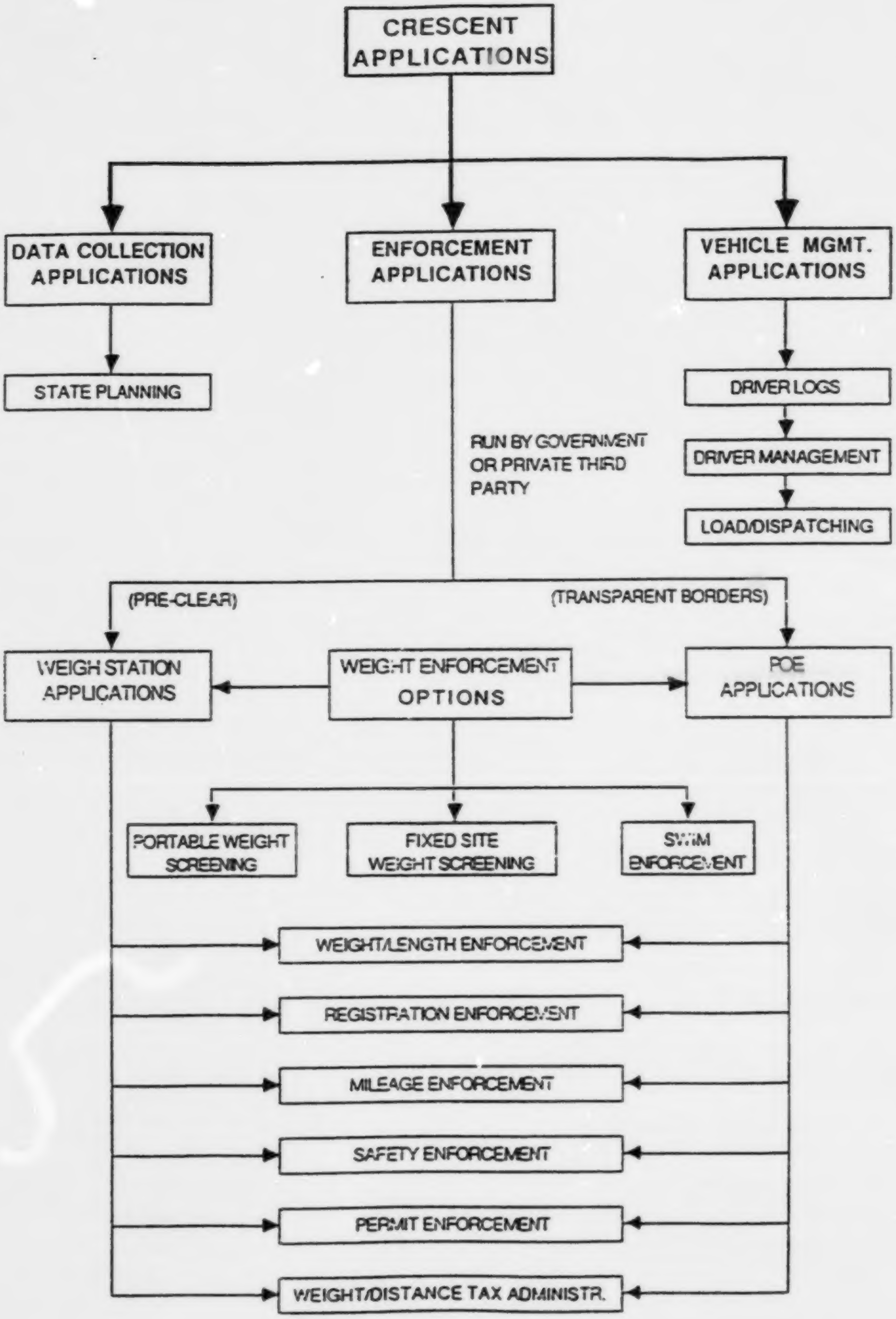

BRITISH COLUMBIA
HOPE
WHITE ROCK
BOWHILL
EVERETT
SEA-TAC
FORT LEWIS
KELSO
VANCOUVER
TIGARD
WOODBURN
JEFFERSON
EUGENE
I-5
WILBUR
BOOTH RANCH
ASHLAND
MT SHASTA
REDDING
LODI
SANTA NELLA
BAKERSFIELD
WHEELER RIDGE
NEWHALL
BANNING
INDIO
EHRENBERG
TONOPAH
S. PHOENIX
MARANA
I-10
LORDSBURG
DEMING
BENSON
SAN SIMON
BERINO
EL PASO
GAINESVILLE
CANTON
SWEETWATER
JUNCTION
SEQUIN

EXHIBIT 45c

CRESCENT APPLICATIONS


CRESCENT APPLICATIONS
DATA COLLECTION APPLICATIONS
ENFORCEMENT APPLICATIONS
VEHICLE MGMT. APPLICATIONS
STATE PLANNING
DRIVER LOGS
DRIVER MANAGEMENT
LOAD/DISPATCHING
RUN BY GOVERNMENT OR PRIVATE THIRD PARTY
(PRE-CLEAR)
(TRANSPARENT BORDERS)
WEIGH STATION APPLICATIONS
WEIGHT ENFORCEMENT OPTIONS
POE APPLICATIONS
PORTABLE WEIGHT SCREENING
FIXED SITE WEIGHT SCREENING
SWIM ENFORCEMENT
WEIGHT/LENGTH ENFORCEMENT
REGISTRATION ENFORCEMENT
MILEAGE ENFORCEMENT
SAFETY ENFORCEMENT
PERMIT ENFORCEMENT
WEIGHT/DISTANCE TAX ADMINISTR.

- Vehicle management
  - automated driver logs
  - driver management
  - load management and dispatching.

5.3.2 AWACS

The Automatic Weight and Classification System (AWACS) project was a demonstration sponsored by Iowa and Minnesota Departments of Transportation and the Federal Highway Administration (FHWA). The project was undertaken by Castle Rock Consultants as prime contractor with GK Instruments as a subcontractor. The main objective of the project was to establish the performance of a low-cost truck weight and classification system based on piezo-electric sensors and to produce open specifications for the system. The overall intent of the project was to support and encourage transfer to research knowledge to system manufacturers.

The project covered the following areas:

- fundamental properties of piezo-electric load transducers
- effectiveness of alternative transducer mounting techniques
- interpretation and processing of signals from piezo-electric systems
- transducer assembly performance
- evaluation of system through laboratory and field trials.

5.3.3 Virginia Fastoll Project

The objective of this project is to install an AVI-based electronic toll collection system on the Dulles Toll Road in Northern Virginia. The project is sponsored by Virginia Department of Transportation with Castle Rock Consultants as the prime contractor. Fastoll will utilize open, generic specifications for the AVI and conventional toll equipment developed by the contractor. The AVI specification will be based upon that developed for HELP.

The primary objectives of the Fastoll system are:

1./ Increase throughput. This is the major objective of the implementation of a Fastoll system. Existing toll collection methods are time consuming and can cause delays. The Fastoll system will aim to significantly increase throughput and consequently reduce delays for users.

2. Good audit control. The use of a Fastoll system should facilitate tight audit control of automated toll collection, ensuring that payment is collected from all vehicles and that tolls can be traced through the whole accounting system.

3. High level of voluntary participation. A basic precept of the project is that participation in a Fastoll system will be voluntary, with the retention of conventional facilities for non-Fastoll vehicles. User acceptance is a vital factor in the success of the Fastoll system, and efforts must be made wherever possible to ensure that the system is attractive to the users.

4. Reliable performance. Toll collection is a demanding function requiring 24-hour performance, virtually error free. The system must be robust and flexible enough to provide full service to the public at all times, at an affordable maintenance cost. The integrated toll collection system will comprise of nine major elements. These are as follows:
   - traffic signs and overhead lane control
   - pre-classification sub-system
   - toll indicators and barriers
   - payment sub-system
   - AVI sub-system
   - vehicle audit sub-system
   - security and enforcement sub-system
   - lane controller sub-system
   - computer and communication sub-system.

The overall system design and the layout of the equipment in the toll lane are illustrated in Exhibits 46a and 46b. This two and a half year project, which started December 1987 comprises a total of eight phases as follows:
Phase 1 – feasibility analysis
Phase 2 – concept development
Phase 3 – detailed system design
Phase 4 – plans and specification
Phase 5 – equipment procurement
Phase 6 – acceptance tests
Phase 7 – installation and commissioning
Phase 8 – system evaluation.

5.3.4 Other Electronic Toll Collection Projects

a) Coronado Bridge, San Diego
Operator: California Department of Transportation
Equipment Vendor: SAIC
Number of equipped vehicles: 1000

EXHIBIT 46a

FASTOLL SYSTEM DESIGN

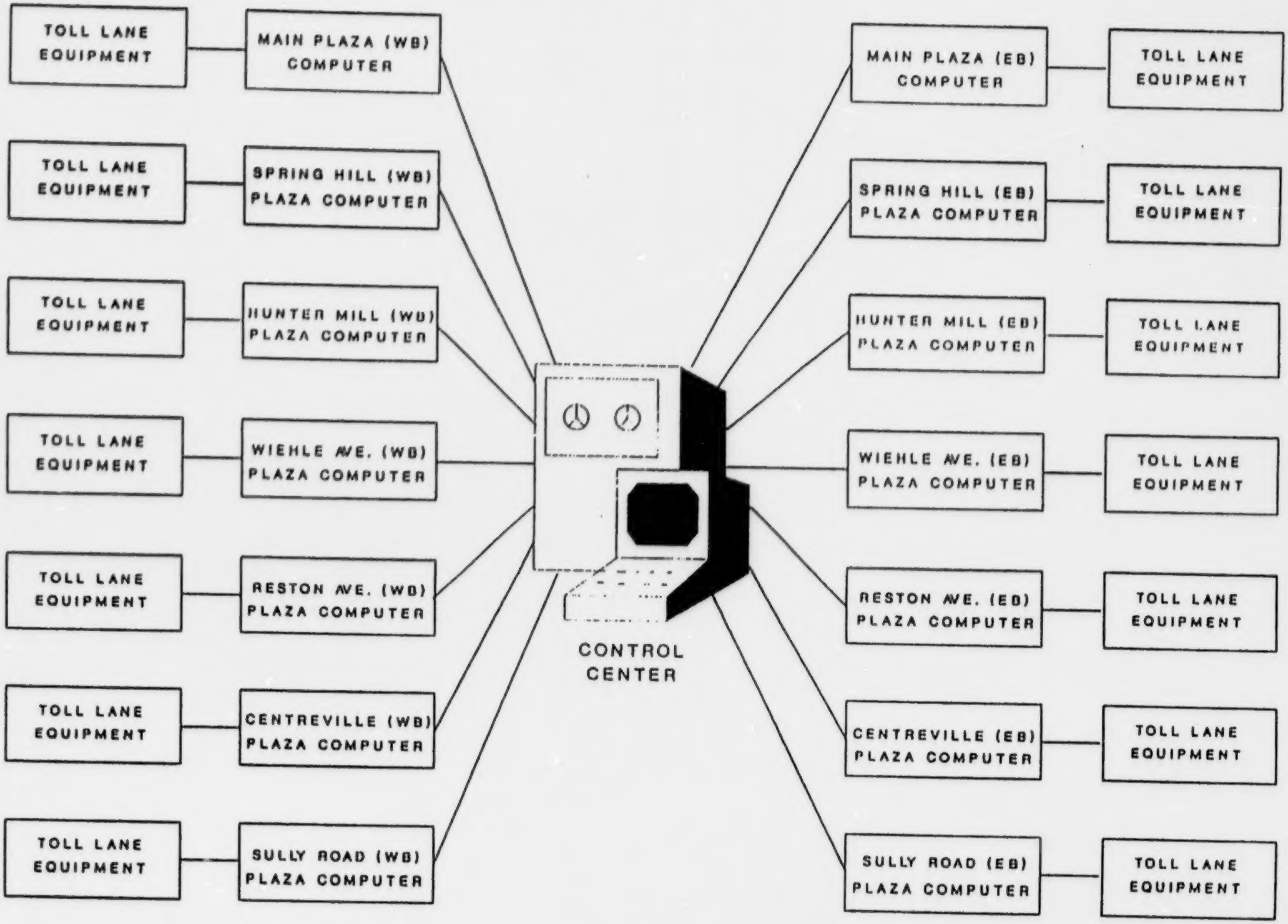
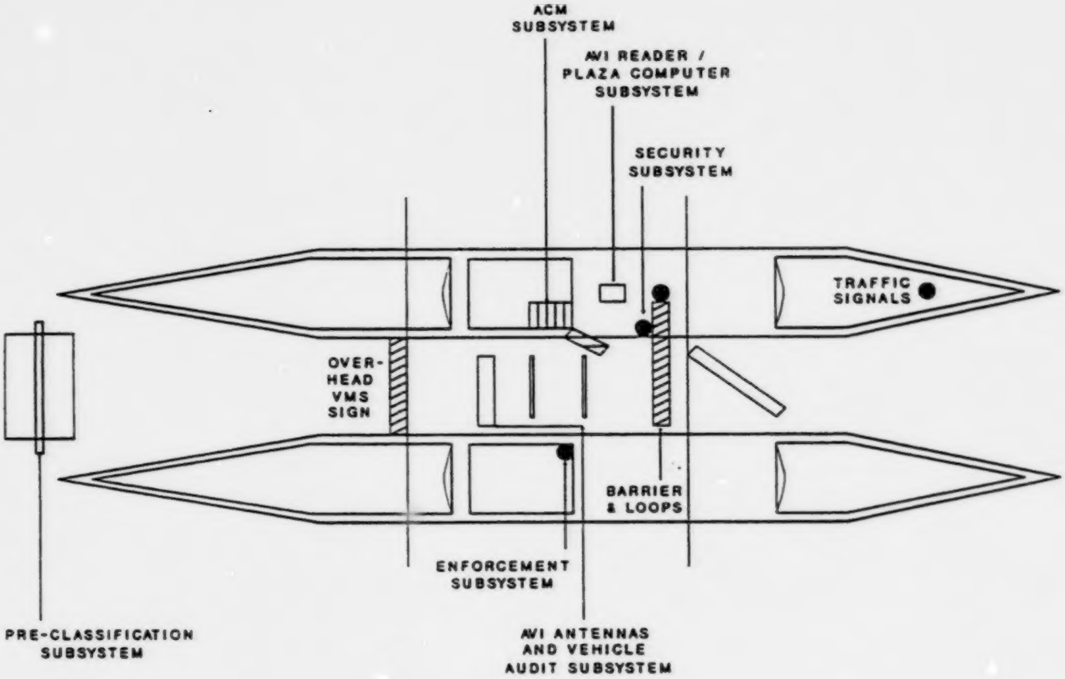
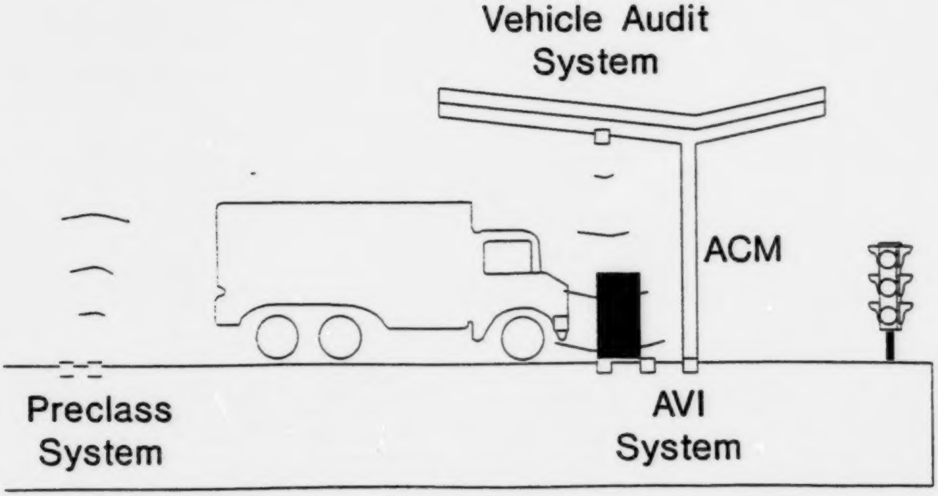

TOLL LANE EQUIPMENT
MAIN PLAZA (WB) COMPUTER
TOLL LANE EQUIPMENT
SPRING HILL (WB) PLAZA COMPUTER
TOLL LANE EQUIPMENT
HUNTER MILL (WB) PLAZA COMPUTER
TOLL LANE EQUIPMENT
WIEHLE AVE. (WB) PLAZA COMPUTER
TOLL LANE EQUIPMENT
RESTON AVE. (WB) PLAZA COMPUTER
TOLL LANE EQUIPMENT
CENTREVILLE (WB) PLAZA COMPUTER
TOLL LANE EQUIPMENT
SULLY ROAD (WB) PLAZA COMPUTER
CONTROL CENTER
MAIN PLAZA (EB) COMPUTER
TOLL LANE EQUIPMENT
SPRING HILL (EB) PLAZA COMPUTER
TOLL LANE EQUIPMENT
HUNTER MILL (EB) PLAZA COMPUTER
TOLL LANE EQUIPMENT
WIEHLE AVE. (EB) PLAZA COMPUTER
TOLL LANE EQUIPMENT
RESTON AVE. (EB) PLAZA COMPUTER
TOLL LANE EQUIPMENT
CENTREVILLE (EB) PLAZA COMPUTER
TOLL LANE EQUIPMENT
SULLY ROAD (EB) PLAZA COMPUTER
TOLL LANE EQUIPMENT

EXHIBIT 46b

FASTOLL EQUIPMENT LAYOUT


ACM SUBSYSTEM
AVI READER / PLAZA COMPUTER SUBSYSTEM
SECURITY SUBSYSTEM
TRAFFIC SIGNALS
OVER-HEAD VMS SIGN
BARRIER & LOOPS
ENFORCEMENT SUBSYSTEM
PRE-CLASSIFICATION SUBSYSTEM
AVI ANTENNAS AND VEHICLE AUDIT SUBSYSTEM

Toll Lane Equipment


Vehicle Audit System
ACM
Preclass System
AVI System

b) Dallas North Tollway, Dallas, Texas
Operator, Texas Turnpike Authority
Equipment vendor: Amtech Corporation
Number of equipped vehicles: 21 500 (all 2-axle)

c) New Orleans Bridge, Louisiana
Operator: Mississippi River Bridge Authority
Equipment vendor: Amtech Corporation
Number of equipped vehicles: 13 000 (from motorcycles to 18-wheelers)

5.3.5 TravTek

TravTek, short for travel technology, is a major IVHS demonstration project that will provide navigation assistance, real-time traffic information, route selection and other information to tourists and business travelers in the Orlando area. A recent press release is included in Appendix H.

5.4 Canadian Projects

5.4.1 Transport Canada Projects

Transport Canada is funding two projects, in addition to this one, directly relating to mobile information systems:

a) Potential of Emerging Technologies on Future Navigation Systems in the Canadian Transportation Sector

Objective: To assess potential of emerging technologies for future navigation systems in transportation.

Scope
- identify major navigation-related technological developments
- assess impact of developments on navigation systems
- evaluate related national strengths and weaknesses
- recommend research priorities

Contractor: Department of Surveying Engineering
The University of Calgary

Final Report: scheduled for April 1990.

b) Needs and Opportunities for Motor Vehicle Safety and Productivity R&D in Canada

Objectives: To provide strategic direction and to develop a framework for a long-term national R&D program in the area of motor vehicle safety and productivity, and to help both the Research and Development Directorate and Road Safety and Motor Vehicle Regulation Directorate of Transport Canada in preparing their long range R&D plans.

Issues to be addressed:
- adequacy of road transport research in Canada
- role of the Federal Government
- need for regulatory research and related data bases
- safety/productivity impacts of futuristics technologies under development
- strategic consideration for long term safety R&D program including resources and institutional arrangements

Scope
- focus on motor vehicle safety
- productivity considered in the context of safety to deal with safety/productivity counterimpacts
- road transport system: roadway, vehicle, driver, operating environment

Contractor: ADI Ltd. in conjunction with Davis Engineering & Booz-Allen &
Hamilton & HumanTech

Final Report: scheduled for May 1990.

c) Other Related Studies
- Air Navigation Plan
- Marine Radionavigation Statement
- Radionavigation/Location Requirement for Surface

Users in Canada
- Active Control System Cost-Effectiveness Study.

5.4.2 Provincial Projects

The Transportation Control Technology and Systems Office of Ministry of Transportation Ontario has initiated Wide-Area Vehicle Monitoring (WAVM) System project, to promote the application of navigation and communication technologies to the trucking industry.

Telesat Mobile Inc (TMI) of Ottawa now offers a service, the Road KIT, to automatically track each vehicle of a fleet (using Loran-C) and to provide communication (using INMARSAT) between the driver and his/her dispatch centre anywhere in Canada and the continental United States. Two other services are available: the Marine KIT and the Field KIT. By winter 1990/91, Loran-C should cover all of southern Canada. Starting in 1993, the MSAT satellite – which will be dedicated to mobile communications on the L-band – will provide the communication capability.

The federal Department of Communications has purchased 300 units – to be delivered by the end of 1990, in 50 unit lots starting in May. Some 170 field trial proposals and ideas in the road, marine and air sectors are being evaluated, including land ambulance service and a rural school bus operation. First units are designated for a coast guard trial and for use by DOC radio inspectors in northern Ontario.

At present, Telesat Mobile of Ottawa, Frederick Transport of Dundas and Thompson Transport of St Thomas each have one prototype unit in technical trials. Allied Van Lines of Mississauga is planning a trial with five vehicles starting in June 1990, towards a possible purchase of $1.2 M worth of equipment (i.e., dispatch centre, custom fleet management software, and on-board units for 200 vehicles).

In addition to the initial capital cost – of roughly $5600 per on-board unit + $12,000-$15,000 for the dispatch equipment – there is a monthly cost of $89. This provides an hourly position update and four 40-character messages per day. An entry level system with similar communication needs, if leased entirely, would cost roughly $250 per vehicle per month.

Other related Canadian activities include the evaluation of WIM technology by the provinces of Quebec and Ontario, and a vehicle positioning demonstration undertaken by Metropolitan Toronto Ambulance Service.

5.5/ Remarks on Government Regulatory Role

The traditional government role in the area of automotive vehicle monitoring and control systems has been based on Motor Vehicle Safety and Environmental Protection. "Motor vehicle safety" means the performance of motor vehicles or motor vehicle equipment in such a manner that the public is protected against unreasonable risk of accidents occurring as a result of the design, construction or performance of motor vehicles.

The public is also to be protected against unreasonable risk of death or injury to persons in the event accidents do occur, and this includes safety of such vehicles while in non-operational modes. "Environmental Protection" deals with the control of noxious emissions from the automobile, not only during operation; evaporative fumes are also limited by U.S. government specifications. The U.S. Department of Energy has also set forth fuel economy requirements on vehicles for the U.S. market. On a voluntary basis, the industry in Canada is following a similar strategy. The European countries, after dragging their heels for nearly two decades, are finally starting to get tough on automotive emissions – no doubt being encouraged by the sight of evergreen forests turning everbrown.

The issuance of Motor Vehicle Safety Standards is an appropriate role for government. At times this has been highly successful, as well as politically innovative, as in the case of seat belt legislation in Canada and the enforcement activities in provinces like Ontario. The legislation of day-time running lights, coming to effect in 1991, is another example of advanced thinking – albeit several years behind Sweden, for example – on increasing automotive safety.

Due to the global similarity of vehicles and their usage, it is important that governments cooperate with each other to arrive at globally accepted requirements. Federal Motor Vehicle Safety Standard FMVSS-108 being accepted by Canada as Canadian Motor Vehicle Safety Standard CMVSS-108 is an excellent example of cooperative usage of a common requirement.

California's unique emission limits created a significant problem for the automotive industry. The quantity of vehicles affected was marginally large enough to justify the added costs of engineering and manufacturing unique solutions. Unique demands by smaller markets would be unmanageable.

On the other hand, many jurisdictions – battling with severe air pollution problems - now wish they could have joined California; or, at least, that they – or on their behalf the states, provinces and federal governments – would have had the political and economic will to set more stringent automotive emissions standards.

Government also has a role in research, testing, development and educational training in vehicle and traffic safety. Research grants and contractually funded programs should be pursued in favor of maintaining large government agencies to conduct these programs. A modest level of internal government agency research and development should be maintained in order to sustain a reasonable degree of expertise within the governmental agencies so that they can properly administer external contracts.

It is interesting to note that the single most effective U.S. highway safety legislation ever written was taken because of the energy crisis associated with the Arab Oil

Embargo. The 1974 "double-nickle" speed limit ruling of 55 MPH maximum across the United States turned out to create a remarkable drop in highway fatalities. Unfortunately public demand has now brought about relaxation of this ruling, and several states have already raised their speed limits.

In Ontario, the possibility of (selectively) raising the 100 km/h speed limit has been discussed; in practice, this has already happened – to perhaps 120-135 km/h – as current level of speed enforcement can, at best, be called minimal. (Recent enforcement step-up and doubling of fines has, at least temporarily, forced those speeds down by perhaps 15 km/h.)

Municipal governments frequently impact highway safety as a result of their role in new developments that generate traffic flow. Shopping centres, office buildings, housing complexes, etc. are trip generators that can severely impact nearby roadways. It is important that these local government agencies, involved in such commercial developments, recognize the advise from traffic and transportation planners in time – before commitments are being made.

The U.S. National Highway Traffic Safety Administration (NHTSA) reports that seat belts have saved 5734 lives between January 1984 and June 1987. Thirty-one states now have mandatory seat belt usage laws. The NHTSA estimates that the usage of seat belts in those states has risen from 11%, prior to the law, to 48% in 1987. The Federal Government should have placed more pressure on State Governments to enact such laws. Federal Highway Funds could be withheld from states not willing to enact and enforce the seat belt usage laws.

At present, under Federal Motor Vehicle Safety Standard MVSS-208, made effective January 1,1968, seat belts with shoulder harnesses are required only in front seats. Rear seat passengers, equipped only with lap belts, have continued to suffer more severe injuries than those equipped with shoulder harness as well. Since 1972, Federal regulations have required anchorage points in all passenger car vehicles for shoulder harnesses for the rear out-board seats. By 1990, all domestic and most major foreign car makers will be offering rear-seat shoulder harnesses as standard equipment.

The long time lag is caused by public apathy and the car-maker's reluctance to install belts and shoulder straps not demanded by the buying public. Here, both the U.S. and the Canadian federal governments could have played a much larger educational role to bring about public awareness and a natural market demand for these devices. Forcing the car-maker to install safety equipment that the buyers do not want and do not use is an inadequate step. If the belts and shoulder straps are appropriate safety items to be mandated for installation then their usage should also have been mandated nationwide.

The aborted seat-belt ignition interlock law of the early 1970s is a classic example of a good idea scrapped by the legislators who had failed to properly educate the public and were too readily dissuaded by public outrage. Twenty years have gone by during which some thirty thousand more lives could have been saved by seat-belts and shoulder straps. Some sources claim over one hundred thousand lives could have been saved with one hundred percent utilization of seat-belts and shoulder straps during that time span.

There is indeed great inertia against regulating or implementing new technology, even if there is only the most remote possibility that this may not be "what the market wants," while there has been abundant evidence (for years) that headrests for the backseat passengers would save lives and serious injuries, no regulatory agency, nor North American vehicle manufacturer for that matter, has ventured to implement these devices.

In the area of in-vehicle information systems, the likelihood that any regulation would be forthcoming – before wide scale implementation of a (wild) variety of these devices – is small both in U.S. and Canada. However, because of the great potential that these devices hold for increasing road safety – if they are properly designed and installed, and operated in a safe manner – it is imperative, that the required research and demonstration be pursued so that the knowledge base will be equally available to the developers of the systems and the implementors of regulations in this area.

6/ CONCLUDING REMARKS

All hardware technologies necessary for the development of comprehensive mobile information systems, while being continually refined, are essentially available today. There are no technological barriers to system-wide implementation of automatic fleet monitoring systems, in-vehicle navigation/route guidance systems, vehicular monitoring/control systems, and general travel support systems.

This Highway Vehicle Electronics (HVE) Project report, together with the Mobile Information Systems Impact Study (MISIS) report, provides a knowledge platform for reviewing critical issues in the development of on-board electronic technologies toward increasing the safety and productivity of the road transport system.

Parallel to the technological advancements, the pace – in Europe and Japan – of innovation in transport planning, traffic management, and infrastructure policies toward sustainable development is very fast. The momentum in research and demonstration of in-vehicle electronic technologies is increasing. Major long-term financial commitments have been made by the governments, and the automobile and electronics industries. Universities and other research facilities are heavily involved.

The reasons have not changed. Application of micro-electronics to the road transport system is seen as an urgent necessity – for not only as a way to improve road safety and reduce or better manage traffic congestion, but for environmental reasons. And the industrial opportunities to countries willing to invest in the early development work are considered very significant. The potential markets for systems that incorporate all or some of the functional capabilities will be huge in the future. For the equipment manufacturers, commercial and private fleet operators, municipal traffic managers, transit operators and others, and the public-at-large, a lot is at stake.

This has been recognized in the United States. The U.S. DOT has proposed to the Congress a "national cooperative effort to foster the development, demonstration and deployment of Intelligent Vehicle-Highway System (IVHS) technologies." The program will consist of Advanced Traffic Management Systems (ATMS), Advanced Driver Information Systems (ADIS), Advanced Vehicle Control Systems (AVCS), and Commercial Vehicle Operations (CVO). Major research projects are already underway in California, Michigan, and other states – and TravTek, a field demonstration, is just getting under way in Orlando.

There is no question that Canada must establish its own IVHS program to safeguard its own interests and to ensure that we do not fall behind in a critical high technology/applications research area. Only from the strength of our own program, can we hope to fully benefit from the cooperative research and development opportunities that are available now and that will arise in the future. Where Canada already has access to foreign programs these opportunities should be promptly exploited.

There is an urgent need to establish an active Canadian technology strategy in the whole IVHS area.

REFERENCES

[1] Parviainen, J. A., MOBILE INFORMATION SYSTEMS IMPACT STUDY, Parviainen & Assoc., French R. L/French & Assoc., Zwahlen H T/Ohio University, Ministry of Transportation Ontario and Transportation Development Centre/Transport Canada, August 1988.

[2] THE DYNAMICS OF VEHICLES ON ROADS AND ON TRACKS, Proceedings of 5th VSD – 2nd International Union of Theoretical and Applied Mechanics (IUTAM) Symposium, Vienna/Austria, September 19-23,1977, (ISBN 90265-0270-2).

[3] Davies, P., Ayland N D/Castle Rock Consultants, CURRENT RESEARCH EFFORTS IN AUTOMATIC VEHICLE IDENTIFICATION, Presented at SAE West Coast Meeting and Exposition, Los Angeles/California, 1986.

[4] ARRTS SYSTEMS, AI Corporation, Information Brochure, 1984.

[5] AUTOMATIC IDENTIFICATION, XCI Corporation, Information Brochure, 1986.

[6] French, R. L., and G.M. Lang, AUTOMATIC ROUTE CONTROL SYSTEM, IEEE Transactions on Vehicular Technology: Vol VT-22/No 2, May 1973.

[7] French, R L., IN-VEHICLE ROUTE GUIDANCE IN THE UNITED STATES: 1910-1985, Proceedings of IEE, 2nd International Conference on Road Traffic Control, London 1986.

[8] Stansell, T., THE TRANSIT NAVIGATION SATELLITE SYSTEM, A/Magnavox Co, Torrance/California, 1978.

[9] Stansell, T., THE MANY FACES OF TRANSIT, A/Magnavox Co, Navigation: Vol 25/No 1, 1978.

[10] Moroney, M J., THE U.S. FEDERAL RADIONAVIGATION PLAN, Presented at NAV-85 – Royal Institute of Navigation Conference on Land Navigation and Location for Mobile Applications, York, 1985.

[11] Meyer, S. F., DO YOU KNOW WHERE YOUR TRUCKS ARE? Transport Topics, May 25, 1987.

[12] Lert, P., GEOSTAR'S SUPER SATNAV SYSTEM, Professional Pilot, April 1984.

[13] Thomas, A.M., ADULT BASIC EDUCATION AND LITERACY ACTIVITIES IN CANADA, 1975-1976, World Literacy of Canada, Toronto, 1976.

[14] Bainbridge, L., IRONIES OF AUTOMATION IN NEW TECHNLOGY AND HUMAN ERROR, ed. J. Rasmussen, K. Duncan, and J. Leplat, pp. 271-283, John Wiley and Sons, Toronto, 1987.

[15] Streeter, L.A., D. Vitello, and S.A. Wonsiewicz, HOW TO TELL PEOPLE WHERE TO GO: COMPARING NAVIGATIONAL AIDS, pp. 549-562, International Journal of Man-Machine Studies, 22, 1985.

[16] Gaines, B.R., and N. Moray, DEVELOPMENT OF PERFORMANCE MEASURES FOR COMPUTER-BASED MAN-MACHINE INTERFACES, Final Report DCIEM-PEF-FIN: July 1985, Defence and Civil Institute of Environmental Medicine, Downsview, Ontario, 1985.

[17] Bastow, D., CAR SUSPENSION AND HANDLING (2nd Edition/last chapter), SAE No. B-518, ISBN 0-7273-0316-3.

[18] Berthiaume Clement, A STUDY OF ACTIVE SUSPENSIONS FOR HEAVY VEHICLES, Transport Canada Report No.TP 8399E (potential advantages of active suspension for heavy vehicles)

BIBLIOGRAPHY

[1] Bailey, M. E., THE BBC CARFAX SYSTEM, Proceedings of the 2nd IEE International Conference on Automotive Electronics, London, 1979.

[2] ALI - DESTINATION-GUIDANCE SYSTEM, Blaupunkt, Publicity Brochure, 1986.

[3] Braegas, P., FUNCTION, EQUIPMENT AND FIELD TESTING OF A ROUTE GUIDANCE AND INFORMATION SYSTEM FOR DRIVERS, IEEE Transactions on Vehicular Technology: Vol VT-29/No 2/pp 216-225, May 1980.

[4] Braegas, P., and Zechnall W/Bosch-Blaupunkt, INFLUENCING TRAFFIC TODAY - THE ENTIRE TECHNICAL CONCEPT FOR THE FUTURE, Internal Document, 1985.

[5] Castle Rock Consultants, ASSESSMENT OF ADVANCED TECHNOLOGIES FOR RELIEVING URBAN TRAFFIC CONGESTION, NCHRP Project 3-38(1), Draft Interim Report, Feb 1988.

[6] Dudek, C. L., R.D. Huchingson, and R.Q. Bracket, STUDIES OF HIGHWAY ADVISORY RADIO MESSAGES FOR ROUTE DIVERSION, Transportation Research Record 904.

[7] European Broadcasting Union, SPECIFICATION OF THE RADIO DATA SYSTEM (RDS) FOR VHF/FM SOUND BROADCASTING, Document Tech. 3244-E, EBU, Brussels, 1984.

[8] HIGHWAY ADVISORY RADIO MESSAGE DEVELOPMENT GUIDE, FHWA/Office of Research and Development, Report FHWA/RD-82/059, Washington D.C., 1982.

[9] TRACKER, GEC Traffic Automation Ltd, Information Leaflet, Borehamwood/U.K., 1986.

[10] Giesa, S., and K. Everts, ARIAM: CAR-DRIVER RADIO INFORMATION ON THE BASIS OF AUTOMATIC INCIDENT DETECTION, Traffic Engineering and Control, June 1987.

[11] Gillan, W. J., A TRAFFIC INFORMATION BROADCASTING SYSTEM, Proceedings of the Seminar on Traffic and Environmental Management, PTRC Annual Summer Meeting, Warwick/U.K., 1980.

[12] Honey, S. K., M.W. White, and W.B. Zavoli Etak, EXTENDING LOW COST LAND NAVIGATION INTO SYSTEMS INFORMATION DISTRIBUTION AND CONTROL, Paper presented at IEEE Position Location and Navigation Symposium, Las Vegas/Nevada, November 1986.

[13] AUTOMATIC RADIO INFORMATION (ARI) – APPLICATION IN EUROPE AND THE U.S., JHK and Associates, Summary record of the Conference on In-vehicular Motorist Information Systems, sponsored by Office of Research/FHWA, 1984.

[14] DRIVER INFORMATION AND MOTORIST AID HARDWARE, Mammano F J/FHWA, IEEE Transactions on Vehicular Technology: Vol VT-29/No 2/pp 161-173, May 80.

[15] McEwan, D., RADIO IN THE '80'S – BROADCASTING AND THE IDEAL SOUND RECEIVER OF THE FUTURE, Wireless World: Vol 83, May 1987.

[16] METS TRACKER METS Inc, Information Brochure, Pompano Beach/FL, 1986.

[17] ROAD AND AUTOMOBILE COMMUNICATION SYSTEM, Ministry of Construction and Highway Industry Development Organization, Tokyo/Japan, 1987.

[18] Monty, A. B., THE ATLAS PROJECT – COMMUNICATION BETWEEN DRIVER, AUTOMOBILE AND ENVIRONMENT, Proceedings of the PTRC Seminar on Information Technology in Transport and Tourism, University of Bath, U.K., 1987.

[19] Nelson, H., and H. Bluethenthal, AUTOMATIC AUDIO SIGNING LITERATURE SURVEY ANALYSIS, FHWA Report FHWA/RD-81/097, 1981.

[20] Ott, G. D., VEHICLE LOCATION IN CELLULAR MOBILE RADIO SYSTEMS, IEEE Transactions on Vehicular Technology: Vol VT-26/No 1/pp 43-60, February 1977.

[21] Ruenaufer P,, THE GERMAN ROUTE GUIDANCE SYSTEM ALI – RESULTS OF THE ONE YEAR FIELD TEST, Proceedings of the IEE International Conference on Road Traffic Signalling, London, 1982.

[22] Salas, G., HIGHWAY CODING FOR ROUTE DESIGNATION AND POSITION DESCRIPTION, Highway Research Record No 265: pp 31-49, 1968.

[23] Sandoval, V., THE ADVENT OF INFORMATION TECHNOLOGY IN ROAD TRANSPORT IN FRANCE, Proceedings of the PTRC Seminar on Information Technology in Transport and Tourism, University of Bath, U.K., 1987.

[24] Schneider, H. W., ARIAM – A CAR-DRIVER RADIO INFORMATION SYSTEM WITH AUTOMATIC TEXT ARRANGEMENT AND DISPLAY, Proceedings of the International Seminar on Electronics and Traffic on Major Roads – Technical, Reglementary and Ergonomic Aspects, Commission of the European Communities, Paris, June 1985.

[25] Shibata, M., EXPERIMENTAL STUDY ON ROAD/AUTOMOBILE COMMUNICATION SYSTEM IN JAPAN, Paper at OECD Scientific Expert Group MC5 – 3rd meeting, Tsukuba, Japan, 2 June 87.

[26] AUTOTRAC – AUTOMATIC VEHICLE LOCATION SYSTEM, Spectrum Cellular Corporation, Information Leaflet, 1986.

[27] REPORT OF THE WORKING GROUP ON THE BROADCASTING OF TRAFFIC INFORMATION, Transport and Road Research Laboratory, Supplementary Report 506, Crowthorne/U.K., 1979.

[28] Turnage, H.C., HIGHWAY ADVISORY RADIO, IEEE Transactions on Vehicular Technology: Vol VT-29/No 2/pp 183-191, May 1980.

[29] Turnage, H.C., DEVELOPMENT OF AUTOMATIC HIGHWAY ADVISORY RADIO IN THE UNITED STATES, Proceedings of the IEE International Conference on Road Traffic Signalling: pp 156-158, London, 1982.

[30] von Tomkewitsch, R., ALI-SCOUT – A UNIVERSAL GUIDANCE AND INFORMATION SYSTEM FOR ROAD TRAFFIC, Proceedings of the 2nd IEE International Conference on Road Traffic Control: pp 22-25, London, 1986.

[31] von Tomkewitsch, R., UNTITLED PAPER presented to the Committee for Road Traffic and Traffic Signs at the Conference of European Ministers of Transport, Berlin, May 1984.

[32] Ribbens, W. B., and N.P. Mansour, UNDERSTANDING AUTOMOTIVE ELECTRONICS, Published by SAMS and Texas Instruments, ISBN 0-672-27017-x Library of Congress Cat # 84-51470, 1986.

[33] Bosch, Robert, AUTOMOTIVE ELECTRIC/ELECTRONIC SYSTEMS, GmbH, Stuttgart/West Germany, ISBN 0-89883-509-7 (available from SAE), 1988.

[34] Weathers, T. and C.C. Hunter, AUTOMOTIVE COMPUTERS AND CONTROL SYSTEMS, Prentice Hall publications, ISBN 0-13-054693-3

[35] AUTOMOTIVE MICROELECTRONICS
LaBella B, ISBN 0-444-87906-4, 1986

[36] AUTOMOTIVE INFORMATION SYSTEMS AND ELECTRONIC DISPLAYS: RECENT DEVELOPMENTS, SAE/SP-89/770 & ISBN 0-89883-697-2, February 1989.

[37] RECENT DEVELOPMENTS IN AUTOMOTIVE ELECTRONIC DISPLAYS AND INFORMATION SYSTEMS SAE/SP-87/734 & ISBN 0-89883-965-3 661-1, February 1987.

APPENDIX A

AUTOMATIC FLEET LOCATION/MONITORING SYSTEMS

BRIEF HISTORY

APPENDIX A

AUTOMATIC FLEET LOCATION/MONITORING SYSTEMS

Brief History

Various systems for remotely monitoring the location and status of individual vehicles have been used as fleet management tools for years, particularly for transit bus schedule control and police car dispatching. The location information thus developed aboard fleet vehicles is almost invariably communicated via radio link to the dispatch centre rather than presented to the driver as in the case of a vehicular navigation system. In the past, such systems have primarily used electronic signposts, although some have used dead reckoning or radio trilateration.

The history of transit bus AVLM began in 1959 with London Transport's Bus Electronic Scanning Indicator (BESI) which was a form of inverse proximity system. Optical scanners mounted on poles at strategic locations along nine of the busiest lines identified passing buses by analyzing patterns of light reflected by bar codes printed on plates attached to their sides. The scanners automatically relayed information on passing buses over dedicated telephone lines to the dispatch office where it was displayed by illuminating corresponding light positions on wall board diagrams of the bus routes. BESI remained in operation until 1975.

A major boost to AVLM activities in the United States occurred in 1970 when the Urban Mass Transit Administration (UMTA) first attempted to develop a framework within which valid comparisons among different AVLM systems could be made. At that time UMTA solicited proposals and selected four companies to develop systems to demonstrate the feasibility of several different AVLM techniques. Three of the selected systems used radio frequency location technology, and one used proximity ("electronic signpost") location technology. Feasibility testing took place in 1972 in Philadelphia, and only the proximity system met the location accuracy requirements of a maximum error of 500 ft per 95 percent of all location indications.

Further development was deemed necessary, and in 1975 UMTA initiated a two-phase program to advance AVLM technology and demonstrate its benefits to transit, police, taxi and para-transit operations. Phase I of the program (conducted again in Philadelphia) was devoted to testing and evaluating four candidate location technology concepts (pulse tri-lateration, LORAN-C, narrow beam and broad beam proximity signpost) selected from a range of industry proposals.

Phase II of the UMTA program began in September 1977 with the award of a contract to Hoffman Information Identification Inc to design, develop and implement a state-of-the-art multiuser AVLM system for operational testing and deployment. The Southern California Rapid Transit District (SCRTD) in Los Angeles was selected as the test site, and the Los Angeles Police Department and Yellow Cab were to participate. However, because of various obstacles, the police and taxi participation did not materialize and an alternative plan was devised to use SCRTD service vehicles and supervisor cars to simulate random route operations.

The primary location technology used in the Los Angeles demonstration consisted of proximity signposts of the broadbeam type (ie. the signal from a single signpost is broad enough to be intercepted by vehicles in all lanes through an intersection). Battery-powered transmitters broadcasting a unique digital code every 666 milliseconds at 49.860 Hz were installed at intervals of 250-300 m along the bus routes. As part of the Los Angeles AVLM demonstration, a hybrid location system based on LORAN-C positioning with differential odometer augmentation was tested on random-route service vehicles.

By the early 1980's proximity signposts had become the generally accepted approach to transit bus location monitoring in North America and enjoyed a relatively higher penetration in Canada (eg. with Toronto's TTC) than in the United States. However, signpost approaches are ill-suited to most other types of fleet operations which utilize random routing. Of the three major U.S. police departments that had implemented AVLM systems by 1981, one used proximity signposts (Huntington Beach, California) one used pulse trilateration (Dallas, Texas) and one used dead reckoning augmented by centralized map matching (St. Louis).

APPENDIX B

MOBILE INFORMATION SYSTEMS IMPACT STUDY

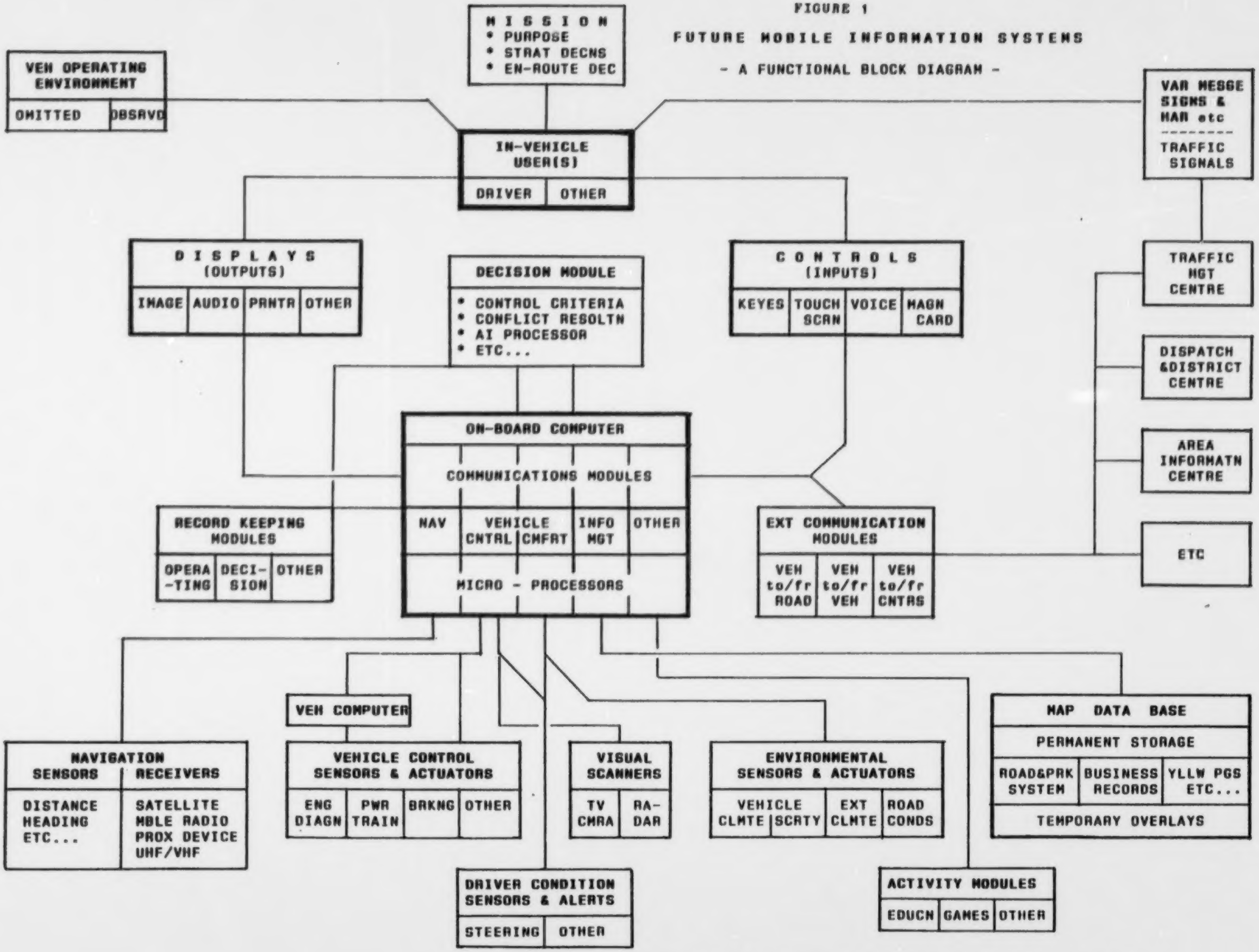
SELECTED EXHIBITS

	MISIS LOCATION
FUTURE MOBILE INFORMATION SYSTEMS A FUNCTIONAL BLOCK DIAGRAM	(EXH 27/P111)
ELECTRONIC DISPLAY DESIGN GUIDE	(EXH 19/P 91)
APPLICATIONS	
TRAVEL ADVISORY	(EXH 21/P105)
FLEET MANAGEMENT	(EXH 22/P106)
TRAFFIC MANAGEMENT	(EXH 23/P107)
MOBILE OFFICE	(EXH 24/P108)
OCCCUPANT ACTIVITY	(EXH 25/P109)
VEHICLE/DRIVER MONITORING & CONTROL	(EXH 26/P110)

FIGURE 1

FUTURE MOBILE INFORMATION SYSTEMS

- A FUNCTIONAL BLOCK DIAGRAM -


MISSION
* PURPOSE
* STRAT DECNS
* EN-ROUTE DEC
VEH OPERATING ENVIRONMENT
OMITTED
OBSRVD
IN-VEHICLE USER(S)
DRIVER
OTHER
VAR MESGE SIGNS & HAR etc
TRAFFIC SIGNALS
DISPLAYS (OUTPUTS)
IMAGE
AUDIO
PRNTR
OTHER
DECISION MODULE
* CONTROL CRITERIA
* CONFLICT RESOLTN
* AI PROCESSOR
* ETC...
CONTROLS (INPUTS)
KEYES
TOUCH SCRN
VOICE
MAGN CARD
TRAFFIC MGT CENTRE
DISPATCH &DISTRICT CENTRE
AREA INFORMATN CENTRE
ETC
ON-BOARD COMPUTER
COMMUNICATIONS MODULES
NAV
VEHICLE CNTRL
CMFRT
INFO MGT
OTHER
MICRO - PROCESSORS
RECORD KEEPING MODULES
OPERA -TING
DECI- SION
OTHER
EXT COMMUNICATION MODULES
VEH to/fr ROAD
VEH to/fr VEH
VEH to/fr CNTRS
VEH COMPUTER
NAVIGATION
SENSORS
RECEIVERS
DISTANCE
HEADING
ETC...
SATELLITE
MBLE RADIO
PROX DEVICE
UHF/VHF
VEHICLE CONTROL SENSORS & ACTUATORS
ENG DIAGN
PWR TRAIN
BRKNG
OTHER
VISUAL SCANNERS
TV CMRA
RA- DAR
ENVIRONMENTAL SENSORS & ACTUATORS
VEHICLE CLMTE
SCRTY
EXT CLMTE
ROAD CONDS
MAP DATA BASE
PERMANENT STORAGE
ROAD&PRK SYSTEM
BUSINESS RECORDS
YLLW PGS ETC...
TEMPORARY OVERLAYS
DRIVER CONDITION SENSORS & ALERTS
STEERING
OTHER
ACTIVITY MODULES
EDUCN
GAMES
OTHER

Source: MOBILE INFORMATION SYSTEMS IMPACT STUDY - Phase I & II
Jouko A Parviainen / Parviainen & Associates, Final Report, 31 Aug 88.

FIGURE 27

FUTURS SYSTÈMES D'INFORMATION EMBARQUÉS

• SCHÉMA DE PRINCIPE •

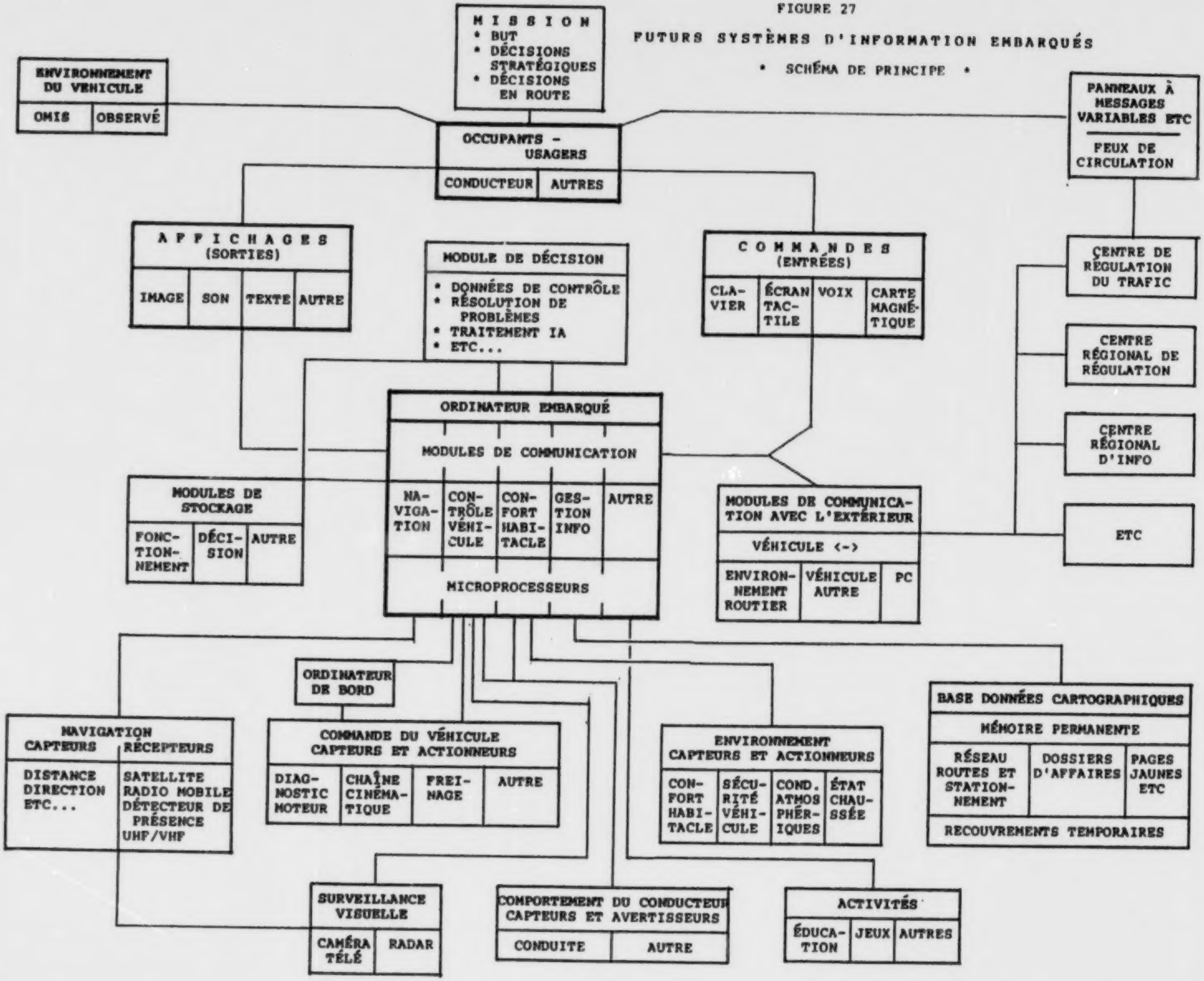

MISSION
• BUT
• DÉCISIONS STRATÉGIQUES
• DÉCISIONS EN ROUTE
ENVIRONNEMENT DU VEHICULE
OMIS
OBSERVÉ
OCCUPANTS - USAGERS
CONDUCTEUR
AUTRES
PANNEAUX À MESSAGES VARIABLES ETC
FEUX DE CIRCULATION
AFFICHAGES (SORTIES)
IMAGE
SON
TEXTE
AUTRE
MODULE DE DÉCISION
• DONNÉES DE CONTRÔLE
• RÉSOLUTION DE PROBLÈMES
• TRAITEMENT IA
• ETC...
COMMANDES (ENTRÉES)
CLAVIER
ÉCRAN TACTILE
VOIX
CARTE MAGNÉTIQUE
CENTRE DE RÉGULATION DU TRAFIC
CENTRE RÉGIONAL DE RÉGULATION
CENTRE RÉGIONAL D'INFO
ETC
ORDINATEUR EMBARQUÉ
MODULES DE COMMUNICATION
NAVIGATION
CONTRÔLE VÉHICULE
CONFORT HABITACLE
GESTION INFO
AUTRE
MICROPROCESSEURS
MODULES DE STOCKAGE
FONCTIONNEMENT
DÉCISION
AUTRE
MODULES DE COMMUNICATION AVEC L'EXTÉRIEUR
VÉHICULE <->
ENVIRONNEMENT ROUTIER
VÉHICULE AUTRE
PC
ORDINATEUR DE BORD
NAVIGATION
CAPTEURS
RÉCEPTEURS
DISTANCE DIRECTION ETC...
SATELLITE RADIO MOBILE DÉTECTEUR DE PRÉSENCE UHF/VHF
COMMANDE DU VÉHICULE CAPTEURS ET ACTIONNEURS
DIAGNOSTIC MOTEUR
CHAÎNE CINÉMATIQUE
FREINAGE
AUTRE
ENVIRONNEMENT CAPTEURS ET ACTIONNEURS
CONFORT HABITACLE
SÉCURITÉ VÉHICULE
COND. ATMOSPHÉRIQUES
ÉTAT CHAUSSÉE
BASE DONNÉES CARTOGRAPHIQUES
MÉMOIRE PERMANENTE
RÉSEAU ROUTES ET STATIONNEMENT
DOSSIERS D'AFFAIRES
PAGES JAUNES ETC
RECOUVREMENTS TEMPORAIRES
SURVEILLANCE VISUELLE
CAMÉRA TÉLÉ
RADAR
COMPORTEMENT DU CONDUCTEUR CAPTEURS ET AVERTISSEURS
CONDUITE
AUTRE
ACTIVITÉS
ÉDUCATION
JEUX
AUTRES

FIGURE 2

ELECTRONIC DISPLAY/CONTROL SYSTEMS DESIGN GUIDE

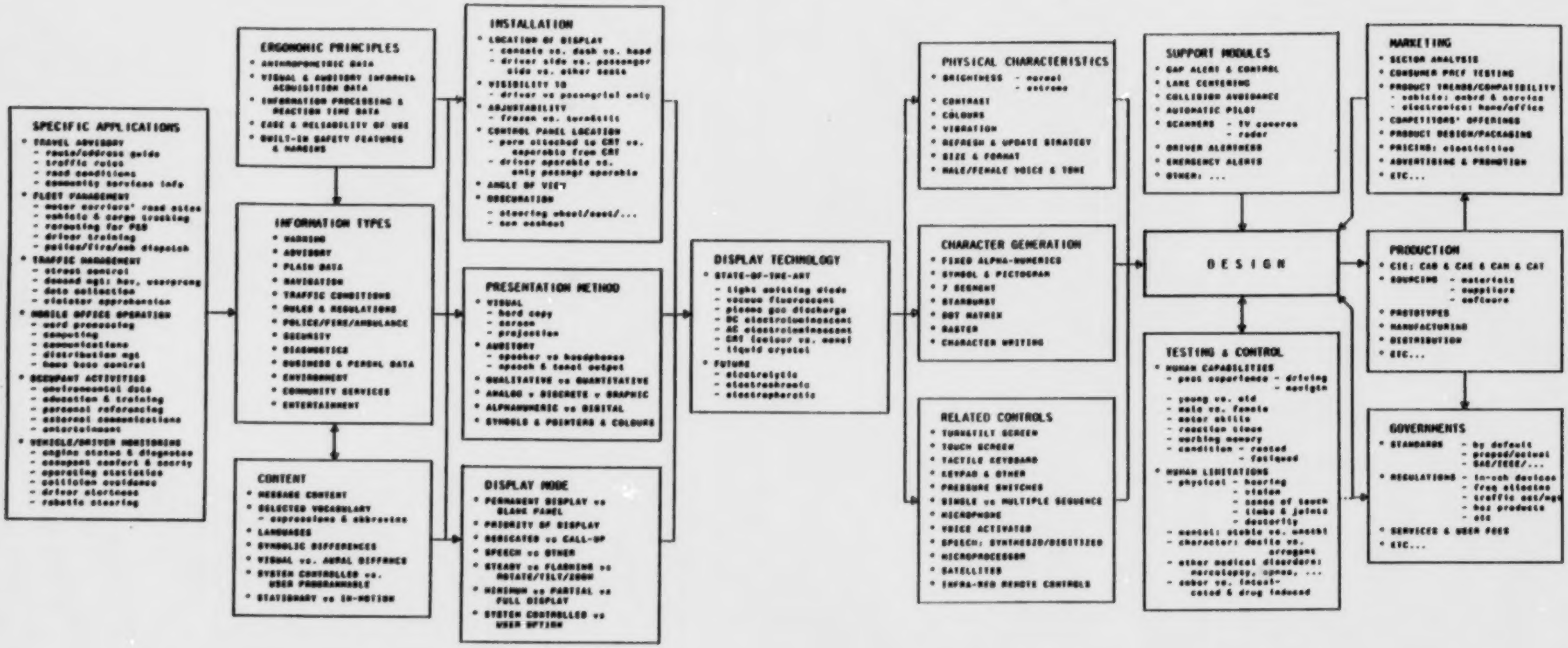

SPECIFIC APPLICATIONS
• TRAVEL ADVISORY
- route/address guide
- traffic rules
- road conditions
- community services info
• FLEET MANAGEMENT
- motor carriers' road sites
- vehicle & cargo tracking
- rerouting for P&D
- driver training
- police/fire/amb dispatch
• TRAFFIC MANAGEMENT
- street control
- demand mgt: hov, userprcng
- data collection
- violator apprehension
• MOBILE OFFICE OPERATION
- word processing
- computing
- communications
- distribution mgt
- home base control
• OCCUPANT ACTIVITIES
- environmental data
- education & training
- personal referencing
- external communications
- entertainment
• VEHICLE/DRIVER MONITORING
- engine status & diagnostics
- occupant comfort & security
- operating statistics
- collision avoidance
- driver alertness
- robotic steering
ERGONOMIC PRINCIPLES
• ANTHROPOMETRIC DATA
• VISUAL & AUDITORY INFORMTN ACQUISITION DATA
• INFORMATION PROCESSING & REACTION TIME DATA
• EASE & RELIABILITY OF USE
• BUILT-IN SAFETY FEATURES & MARGINS
INFORMATION TYPES
• WARNING
• ADVISORY
• PLAIN DATA
• NAVIGATION
• TRAFFIC CONDITIONS
• RULES & REGULATIONS
• POLICE/FIRE/AMBULANCE
• SECURITY
• DIAGNOSTICS
• BUSINESS & PERSNL DATA
• ENVIRONMENT
• COMMUNITY SERVICES
• ENTERTAINMENT
CONTENT
• MESSAGE CONTENT
• SELECTED VOCABULARY
- expressions & abbrevtns
• LANGUAGES
• SYMBOLIC DIFFERENCES
• VISUAL vs. AURAL DIFFRNCE
• SYSTEM CONTROLLED vs. USER PROGRAMMABLE
• STATIONARY vs IN-MOTION
INSTALLATION
• LOCATION OF DISPLAY
- console vs. dash vs. head
- driver side vs. passenger side vs. other seats
• VISIBILITY TO
- driver vs passngr(s) only
• ADJUSTABILITY
- frozen vs. turn&tilt
• CONTROL PANEL LOCATION
- perm attached to CRT vs. separable from CRT
- driver operable vs. only passngr operable
• ANGLE OF VIEW
• OBSCURATION
- steering wheel/seat/...
- sun washout
PRESENTATION METHOD
• VISUAL
- hard copy
- screen
- projection
• AUDITORY
- speaker vs headphones
- speech & tonal output
• QUALITATIVE vs QUANTITATIVE
• ANALOG v DISCRETE v GRAPHIC
• ALPHANUMERIC vs DIGITAL
• SYMBOLS & POINTERS & COLOURS
DISPLAY MODE
• PERMANENT DISPLAY vs BLANK PANEL
• PRIORITY OF DISPLAY
• DEDICATED vs CALL-UP
• SPEECH vs OTHER
• STEADY vs FLASHING vs ROTATE/TILT/ZOOM
• MINIMUM vs PARTIAL vs FULL DISPLAY
• SYSTEM CONTROLLED vs USER OPTION
DISPLAY TECHNOLOGY
• STATE-OF-THE-ART
- light emitting diode
- vacuum fluorescent
- plasma gas discharge
- DC electroluminescent
- AC electroluminescent
- CRT (colour vs. mono)
- liquid crystal
• FUTURE
- electrolytic
- electrochromic
- electrophoretic
PHYSICAL CHARACTERISTICS
• BRIGHTNESS - normal
- extreme
• CONTRAST
• COLOURS
• VIBRATION
• REFRESH & UPDATE STRATEGY
• SIZE & FORMAT
• MALE/FEMALE VOICE & TONE
CHARACTER GENERATION
• FIXED ALPHA-NUMERICS
• SYMBOL & PICTOGRAM
• 7 SEGMENT
• STARBURST
• DOT MATRIX
• RASTER
• CHARACTER WRITING
RELATED CONTROLS
• TURN&TILT SCREEN
• TOUCH SCREEN
• TACTILE KEYBOARD
• KEYPAD & OTHER
• PRESSURE SWITCHES
• SINGLE vs MULTIPLE SEQUENCE
• MICROPHONE
• VOICE ACTIVATED
• SPEECH: SYNTHESZD/DIGITIZED
• MICROPROCESSOR
• SATELLITES
• INFRA-RED REMOTE CONTROLS
SUPPORT MODULES
• GAP ALERT & CONTROL
• LANE CENTERING
• COLLISION AVOIDANCE
• AUTOMATIC PILOT
• SCANNERS - TV cameras
- radar
• DRIVER ALERTNESS
• EMERGENCY ALERTS
• OTHER: ...
D E S I G N
TESTING & CONTROL
• HUMAN CAPABILITIES
- past experience - driving
- navigtn
- young vs. old
- male vs. female
- motor skills
- reaction times
- working memory
- condition - rested
- fatigued
• HUMAN LIMITATIONS
- physical - hearing
- vision
- sense of touch
- limbs & joints
- dexterity
- mental: stable vs. unstbl
- character: docile vs. arrogant
- other medical disorders: narcolepsy, apnea, ...
- sober vs. intoxicated & drug induced
MARKETING
• SECTOR ANALYSIS
• CONSUMER PREF TESTING
• PRODUCT TRENDS/COMPATIBILITY
- vehicle: onbrd & service
- electronics: home/office
• COMPETITORS' OFFERINGS
• PRODUCT DESIGN/PACKAGING
• PRICING: elasticities
• ADVERTISING & PROMOTION
• ETC...
PRODUCTION
• CIE: CAD & CAE & CAM & CAT
• SOURCING - materials
- suppliers
- software
• PROTOTYPES
• MANUFACTURING
• DISTRIBUTION
• ETC...
GOVERNMENTS
• STANDARDS - by default
- propsd/actual
- SAE/IEEE/...
• REGULATIONS - in-veh devices
- freq allocatns
- traffic oat/mgt
- haz products
- etc
• SERVICES & USER FEES
• ETC...

TABLE 2

TRAVEL ADVISORY APPLICATIONS

FUNCTION	FEATURE / CONTENT
ROAD MAP	• general road atlas - road network layout - major attractions (user-selectable categories)
	• street name & route number & section length
	• facility type (limited access, toll, ...) & terrain group (and grade)
	• addresses: odd/even numbers for up-coming block + pin-point location
	• ...
TRAFFIC RULES	• speed limits / parking&turn restrictions / HOV ramps&lanes see: Traffic Mgt
	• weight and height limits / designated routes (trucks, dangerous goods) /...
	• snow clearance (by day and side of street) / special event conditions
	• ...
ROUTE GUIDANCE	• CBD circulation maps (one-way pairs, parking, ...)
	• downtown exit guide: find open freeway entry ramps from anywhere
	• en-route reception of InfoRoad etc + suggested route updates
	• trip computer (with 'planned distances and times vs. actual' comparisons)
	• traffic responsive, dynamic advisory: reception+storage+display of traffic control centre signals (see Trfc Mgt) -> - HAR/AHAR announcements & ramp situation (open/closed; HOVs/SOVs also) - changeable fwy sign messages (actual signs + in-between loctn messages)
	• ...
EMERGENCY RESPONSE	• emergency broadcasts, to capture and store radio and TV alerts (chemical spills, nuclear disasters, ...)
	• search & rescue missions in natural+man-made disasters (guide to/around site)
	• emergency CB: transmission of medical/mechanical/crime/... distress calls
	• ...
PUBLIC SERVICE MESSAGES	• road conditions - weather & traffic situation & accidents and other incidents - road construction and/or maintenance closures - garbage/refuse (strike) disposal emergency regulations
	• general weather alerts: storms, floods, ...
	• special events: content & location & times & parking availability (SOVs & HOVs)
	• transit - route maps & expected next arrival (per bus line and stop number) - park&ride: location, space available, charges
	• passenger & freight terminals - access & circulation & parking - carrier location & departures&/arrivals
	• customs information: rules, line-ups, ...
	• mobile billboard reception: marketing of drunk driving prevention programs, ...
	• ...
ROAD SIDE & COMMUNITY SERVICES INFORMATION	• adjacent land use & block face information
	• fuels & auto repair service / food&lodging / rest&picnic sites / parks / ...
	• electronic bulletin board: community events & ...
	• yellow pages by store type & product category (eg. 'telefind')
	• distributors' lists of retailers by area for certain products
	• subject registers: Thomas Register & Thomcat (= company catalogues)
	• videotex: mobile teleguide kiosk (eg. France's 'Minitel', Canada's 'Alex')
	• shopping centre profiles: layout & store locations by type
	• in-vehicle browsing of electronic stores: viewing of liquid crystal price panels for daily specials, etc
	• in-vehicle audio-visual version of realty 'radio' - property data sheets - floor plans
	• ...

TABLE 3

FLEET MANAGEMENT APPLICATIONS

FUNCTION	FEATURE / CONTENT
VEHICLE & CARGO POSITION TRACKING	• display of vehicle & shipment location at dispatch (control) centre (postal&courier services' admin vehicles/tractor trailers/cargo vans/...)
	• dispatching & rerouting (P&D changes): freight & taxi & emergency vehicles
	• schedule/route/safety adherence -> central dispatch intervention
	• load factor monitoring / operation of destination&passenger information panels
	• emergency vehicles control: police & fire & ambulance & public utilities (reduce response time + increase officer safety)
	• ...
ROUTE GUIDANCE	• motor carriers' specialized road atlas & inter-city routing guides (tolls, ...)
	• industrial site access maps (including advance block signals)
	• maximum dimensions and axle weights: roads, bridges, tunnels
	• municipal regulations: truck routes & operating days/hours
	• routes for heavy specialized carriers & hazardous cargo routes
	• road geometrics alerts: recommended maximum ramp speeds, ...
	• weather alerts: wind, icing of road surface, snow squalls, ...
	• traffic conditions: reasons for delay (incident reports, ...)
	• pre-dep/pre-entry advisory: expected clearance times (by product category)
	• ...
VEHICLE & CARGO & OCCUPANT SECURITY	• automated emergency response system (AERS) (when parked for night, ...)
	• distress calls - unruly passengers (on bus) / heist (of cargo, vehicle) - help request for disabled vehicles / ...
	• convoy management: commercial & private vehicles
	• electronic guard dog
	• ...
DRIVER TRAINING	• video and audio instructions
	• feedback - driving performance: L/100km & gaps & roughness of handling - rules of the road (from map data base or transmitting signs)
	• ...
LAW ENFORCEMENT	• electronic mug book: picture + description of dangerous offenders
	• lost child/adult: picture + description
	• electronic 'pin map' for VICARS (= visual integrated crime analysis reporting system)
	• patrol routes/schedules/sp. targets: display + random changes
	• search perimeter (to be sealed off) & route-by-route progression of search
	• flexible electronic house arrest (ankle bracelet extended to vehicle)
	• locating (=recovery) of stolen vehicles/cargo (req: hidden antenna)
	• ...
AMBULANCE & FIRE	• dangerous chemicals referral system by class + unidentified
	• emergency contacts on building layout and content (of haz products, ...) (transmission of floor plans & equipment locations)
	• emergency contacts on municipal utilities locations
	• incident management teams: command post communications
	• ...

TABLE 4

TRAFFIC MANAGEMENT APPLICATIONS

FUNCTION	FEATURE / CONTENT
STREET CONTROL	• one way streets / reversible streets&lanes / turn restrictions • parking restrictions / snow clearance routes and schedules • loading and unloading rules / ... • high occupancy vehicle - designations and access criteria (eg: > 4 prs/veh) - facility user permits • violator assembly sites (directions from freeway, etc) • emergency clearance: toxic spills & fires & chase & storms & ... • special event management • transmission of the 'content' of electronic destination etc signs • parking: display of pre-purchased electronic tokens at meter • ...
FREEWAY MANAGEMENT	• incident detection & verification & response & surveillance & control measures • transmission of: - corridor conditions reports (individually for each for requested O&D pair) - ramp and lane closures - alternative routes & advisory speeds - pre-trip advisory - average + departure hour specific O&D travel times - suggested alternative departure times
VEHICLE ACCESS	• road use pricing: by peak/off-peak & by vehicle type & by homebase • access control (by transmitting vehicle/driver I.D.) • parking availability & rates by type (all vehicles, HOVs only, ...) • designated routes: trucks & dangerous goods & snow & garbage collection • ...
ENFORCEMENT	• transmission of: - radar/airplane detected excess speeds and illegal maneuvers - electro-optically detected tailgating & misaligned high beam - axle load, route and hour violations - HOV facilities use by single occupant vehicles (SOVs) - typical fine/demerit implications of violation spotted - pull over & stop command • accident reconstruction, ie. 'black box' to backtrack to pre-accident: - driving maneuvers, speed and vehicle position on the lane - non-driving tasks (use of cellular phone, navgtn device controls, ...) • detection and apprehension of (c/w electronic record for courts): - violator vehicles (& violated vehicles, as/if needed) • accumulation of - special merit points - demerit/violation points • ...
TRAFFIC DATA COLLECTION	• trip frequency / O&D / chaining / vehicle occupancy / vehicle type / ... • alternative route selection (vs. advisory sign or HAR message used) • comparative travel times (by time of day & by alternative route) • road and street inventory data and updates • road surface scanning data (from laser cameras) • ...

TABLE 5

MOBILE OFFICE APPLICATIONS

FUNCTION	FEATURE / CONTENT
WORD PROCESSING & COMPUTING	• commuter work stations (in carpools, vanpools and subscription buses)
	• word processing & memo pads
	• study periods: seminar tapes etc
	• calculators: 4-function, business, engineering, scientific
	• compressed registers by product category: Thomas Reg & Thomcat
	• manufacturers lists of wholesalers and distributors
	• industrial sites reference cataloque: boundaries/services & leases & vacancies
	• ...
COMMUNICATIONS	• paging and messages transmission: company + personal
	• automatic dialing (from customer list vs. day's diary order by location)
	• courier status (eg. from FedExp's COSMOSS tracking system)
	• facsimile transmission/reception (& photophone still-pictures)
	• electronic bulletins: infloglobe, stock quotes (portfolio mgt)
	• EDI (electronic data interchange)
	• telemarketing
	- comprehensive client list (including personal data, ...)
	- customer/dealer/supplier locator: map location & postal code
	- daily diary & orders & follow-up call requests
	- electronic scratch pad (retrievable notes during phone calls)
	• ...
FREIGHT	• electronic cargo routing slips (+ wand for loading&unloading in the back)
	• freight - tariffs & rates & regulations
	- hazardous cargo: general data base & recording of route taken
	- emergency contacts and procedures
	- in-vehicle stock control
	• terminals: locations & hours & personnel & line-up number + expected wait times
	• custom operations
	- hours & regulations & duties
	- locations of in-land clearance houses
	- CSS (customs commercial system): tariff classification
	- CADEX (customs automated data exchange program): entry data to customs
	• motor carrier accident report - automatic entries (tachograph + other data)
	- preparation (manual input)
	• travel expenses recording: km/time/fuel allocation & motel invoices
	• accounting: daily transactions
	• ...
HOME BASE CONTROL	• 'smart home' - appliances (pre-arrival turn-on) / security / ...
	- answering machine: messages review & reset
	- ...
	• 'butler-in-the-box' voice command system
	• ...
	• ...
	• ...

TABLE 6

OCCUPANT ACTIVITY APPLICATIONS

FUNCTION	FEATURE / CONTENT
ENVIRONMENT DATA	• adjacent environment: geography & fauna & ... • '4x6 memory cards' + charts on basic sciences • environmental protection/information - data bank on toxic discharges & rain - fundamentals on earth's egosystems - regulations & 'acceptable' limits • recreational and cultural data banks • ...
EDUCATION & TRAINING	• standard and inter-active audio/video courses • encyclopedia & yearbooks & personal interest sheets • science summaries • compressed summaries (of publications) for executives, etc • language training & music studies & ... • calculator functions: 4-function, scientific, business, ... • ...
PERSONAL REFERENCES	• family/friends data base: names, birthdays, addresses, phones, ... • health care - health & diet information - transmission of heart beat pattern, etc - reception of analysis results and emergency advice - en-route/in-vehicle analysis • household finances: purchase records, due dates (automatic flags) • local phone book & community contacts • activities list - todays musts (user selectable time buffers) - household tasks in a video 'cookie-jar' • ...
ENTER-TAINMENT	• games: against computer & amongst occupants • music - CD player control (tracks pre-selection by each individual) - radio stations scanning - composing & play-back (casette recording) • veh<->veh communications: messages / driving 'instructions' / flirting • ...
EXTERNAL COMMUNI-CATIONS	• inter-active responses with external systems - participation in computerized auctions: retail value & highest bid - en-route & pre-arrival - motel bookings (room type & rate & durationof stay) - motel confirmations & cancellations - fast food group orders (express pick-up) - telemarketing: product review & response (with a smart card) - in-vehicle video shopping (eg: 'CanValNet' cable shopping) - libraries' lists of ref material (eg. 'home access' in personal vehicles) - remote access to ATM networks (electronic banking) • ridesharing pick-up/drop-off modifications (veh<->house & veh<->ofc transmition) • electronic hitch-hiking - hitch-hiker and driver registration confirmation - receive destination sought • monitoring of electronic babysitter signal • ...

TABLE 7

VEHICLE/DRIVER MONITORING AND CONTROL APPLICATIONS

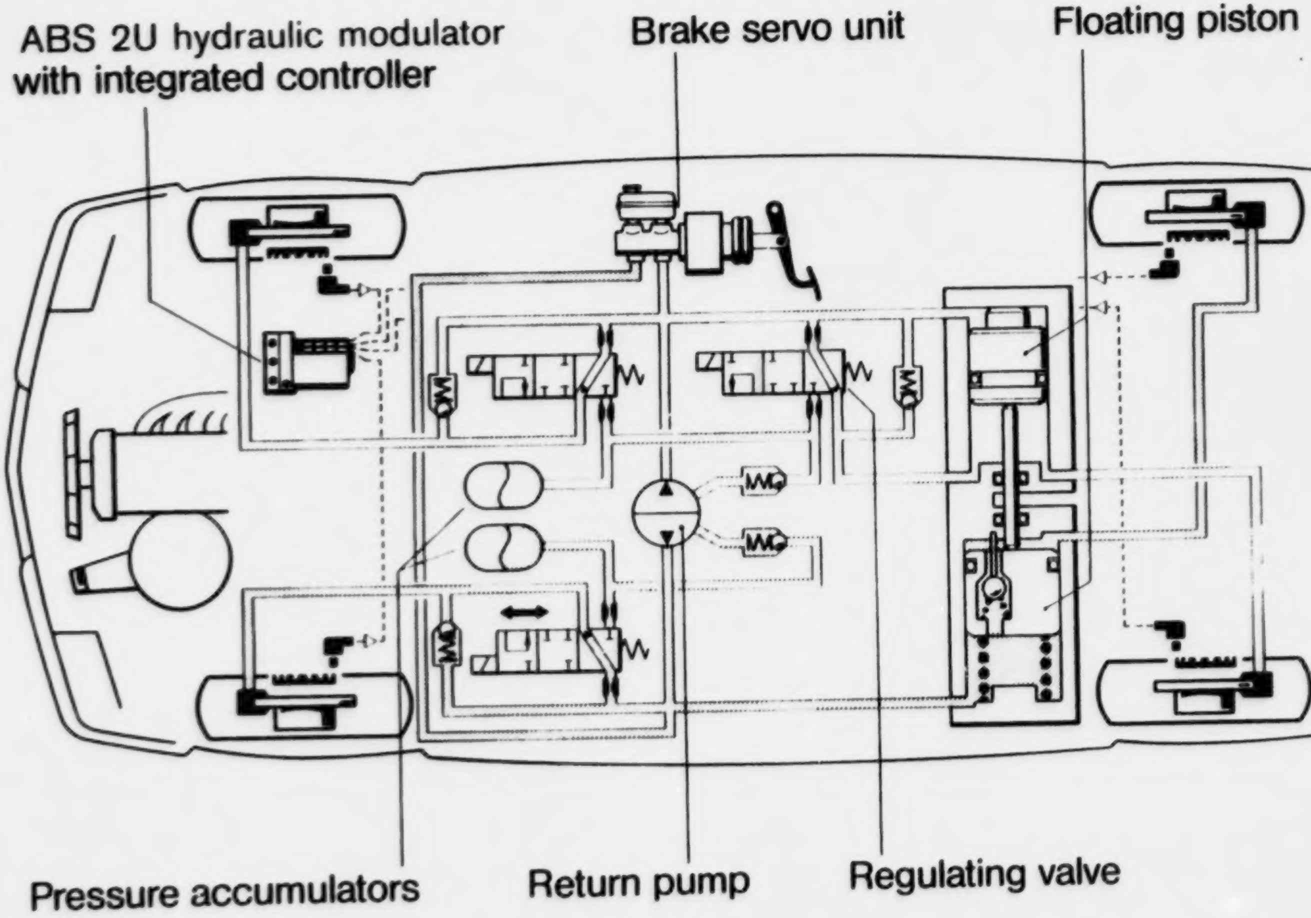
FUNCTION	FEATURE / CONTENT
VEHICLE/ DRIVER MONITORING	• status of vehicle systems - diagnostic displays - anticipated failure alert - response-to-failure tips
	• driver alertness mon. (eg. number of steering corrections per time interval) and alert ('snooze alert') & automatic but limited vehicle response
	• on-board physiological monitoring (eg. in military vehicles)
	• vehicle maintenance - tips (eg. jump start steps to protect modern electronics) - customized work order processing for preventive maintenance - upcoming warranty expiration alerts - calls: tow vehicle availability and rates
	• operating statistics for each driver: h & km & L or kg of fuel & ...
	• manner-of-use record for each driver (with exception alerts): speeds (actual & compared to limits) & idling & abrupt handling
	• ...
	• ...
VEHICLE CONTROL	• collision avoidance systems - minimum gap alert (Rashid VRSS) - weather alert & surface friction alert - suggested maximum speeds
	• rear view display & ultrasonic obstacle warning for backing up
	• night time infrared forward imaging system (obstruction alert)
	• perimeter vision/scanning (for extra long & wide loads)
	• specialized controls/features for handicapped and/or elderly
	• anti-theft device - starting by key code/voice print/smart card - automatic transmission of tracking signal - disabling of essential controls
	• comfort - radio station/tape/CD selection (individualized) - individualized positioning of: seat / int.temp / windows / mirror /
	• ...
	• ...
AUTOMATIC CHAUFFEURING	• automatic highways (median lane control) - steering function - accelerator/brake functions
	• agriculture & mining & manufacturing (robotic steering): computer controlled and steered combines, forklifts, etc
	• man-made and natural disasters response: spills & fires & ...
	• military operations (autonomous land vehicles): surveillance / reconnaissance / advance columns / mine field clearance / ...
	• ...
	• ...

APPENDIX C

AUTOMOTIVE ELECTRONICS

SAMPLE DIAGRAMS

ABS 2U for diagonal dual-circuit brake system


ABS 2U hydraulic modulator with integrated controller
Brake servo unit
Floating piston
Pressure accumulators
Return pump
Regulating valve

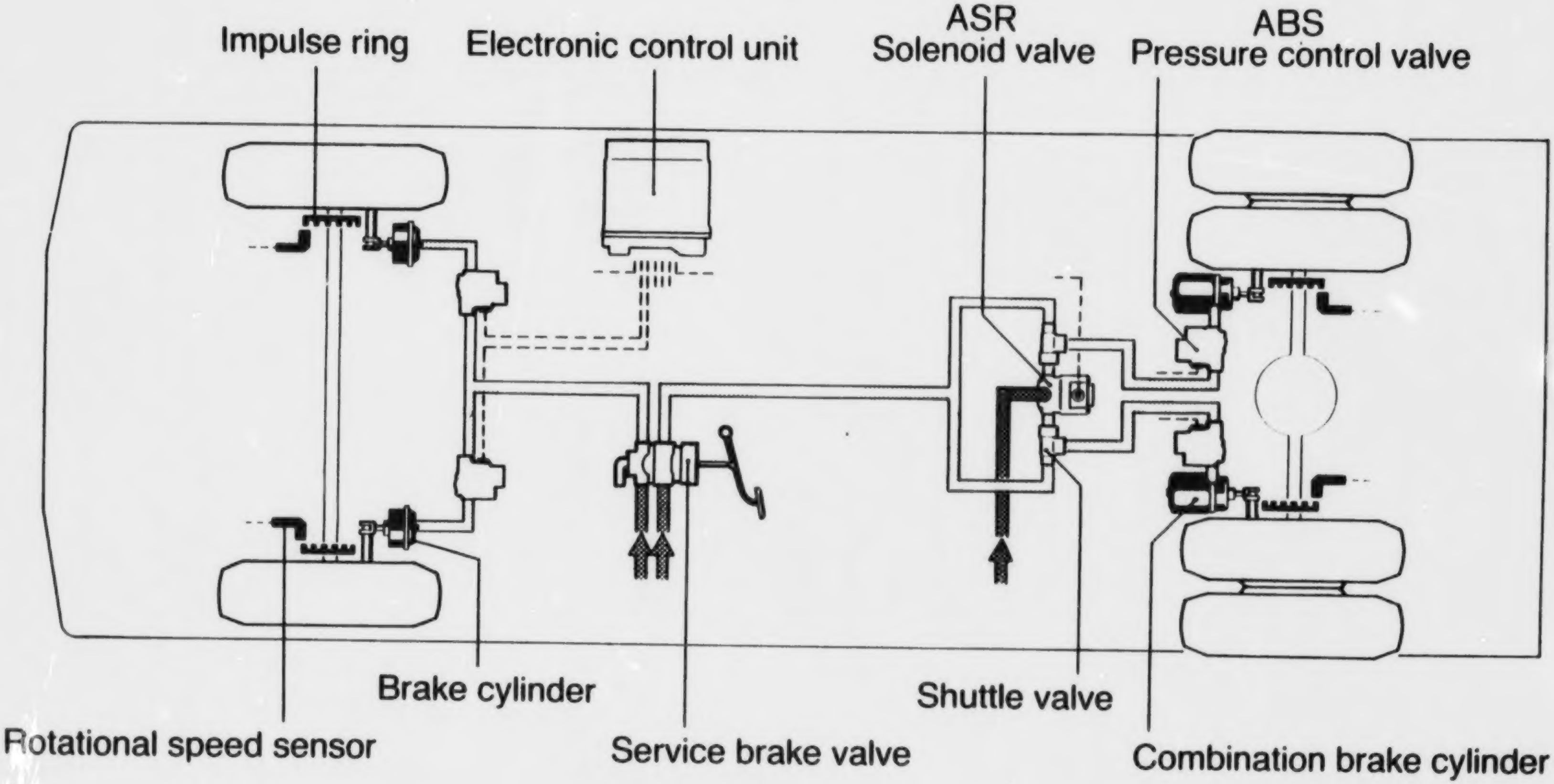
BOSCH

Reproduction free of charge with notation "Bosch Press Photo".
Please send copy to Robert Bosch GmbH, Zentralabteilung Presse.
Information, Postfach 10 60 50, D-7000 Stuttgart 10.

Press photo No
7270

ABS/ASR for Commercial Vehicles

4 sensors/4 channels with single-channel pressure control valve

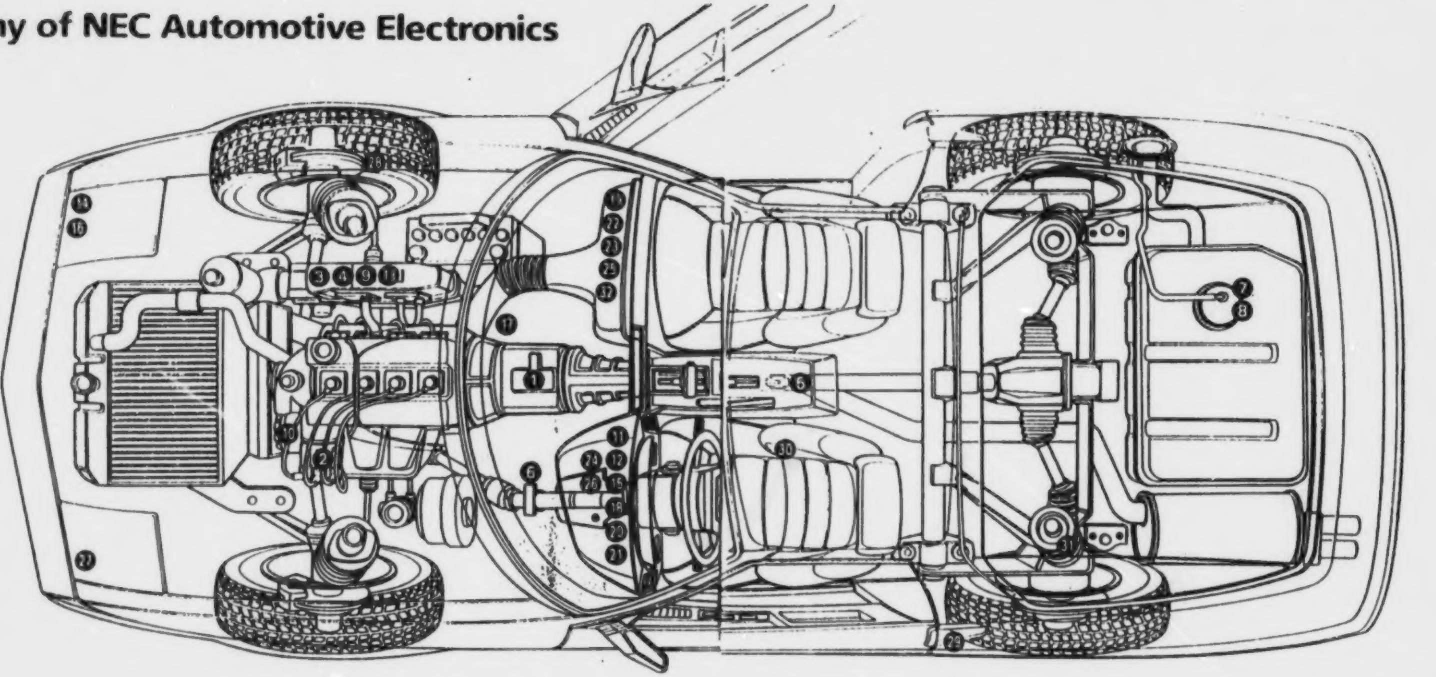

Impulse ring
Electronic control unit
ASR
Solenoid valve
ABS
Pressure control valve
Brake cylinder
Shuttle valve
Rotational speed sensor
Service brake valve
Combination brake cylinder

BOSCH

Reproduction free of charge with notation
"Bosch Press Photo". Please send copy to Robert Bosch GmbH,
Zentralabteilung Presse, Information, Postfach 50, D-7000 Stuttgart 10

Press photo No.
7112e

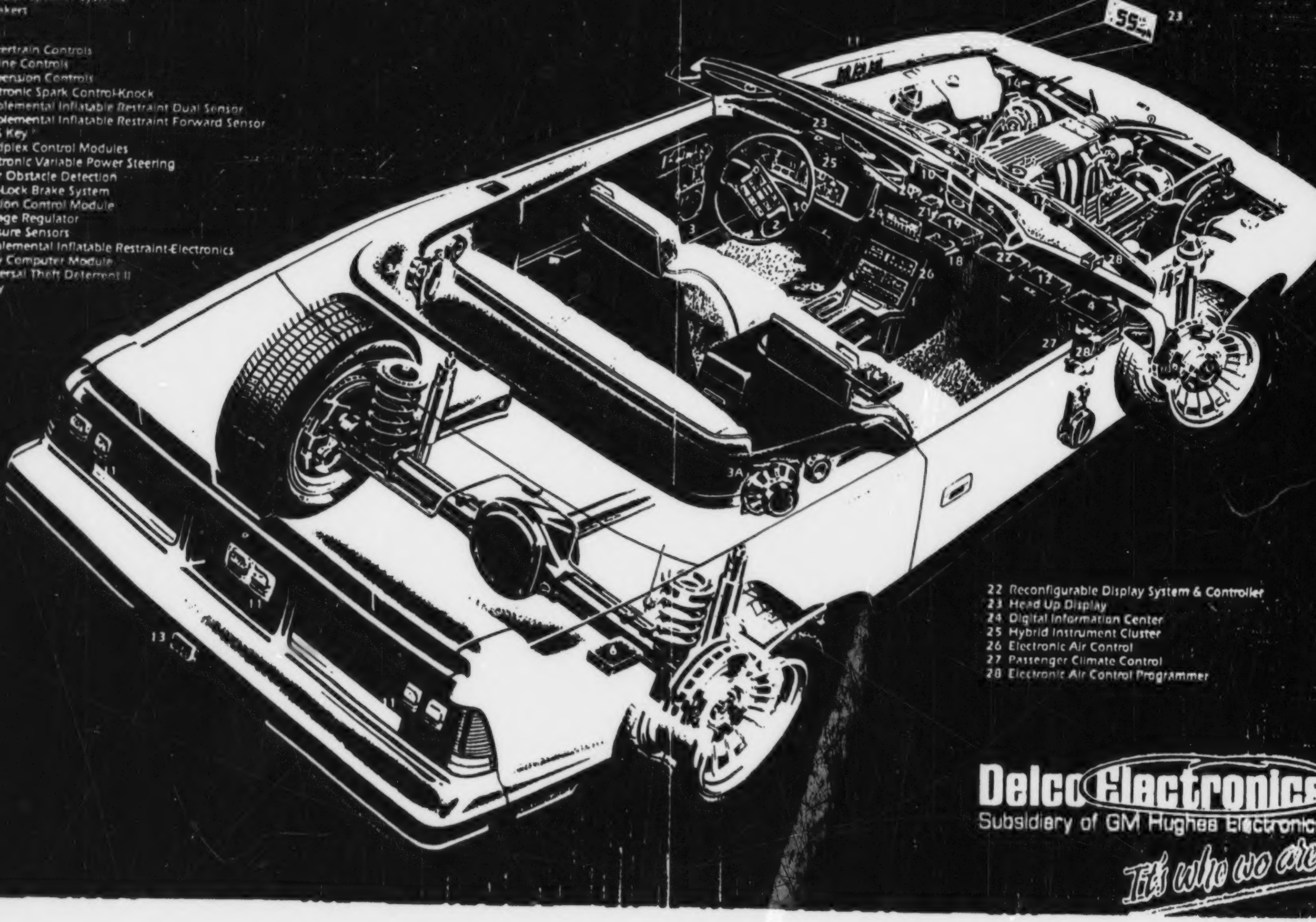
Anatomy of NEC Automotive Electronics



	① Automatic Transmission Control	② Ignition Control	③ Carburetion Control	④ Fuel-Injection Control	⑤ Exhaust Emission Control	⑥ Power-Steering Control	⑦ Fuel Pump Driver	⑧ Fuel Pump Control	⑨ Overall Engine and Fuel Consumption Control	⑩ Voltage Regulation
Transistors/MOS FETs	●	●	●	●	●	●	●	●	●	●
Diodes	●	●	●	●	●	●	●	●	●	●
Linear ICs, Digital ICs, G/A	●	●	●	●	●	●	●	●	●	●
16-, 8-bit Microcomputers	●	●	●	●	●	●	–	–	●	●
4-bit Microcomputers	–	–	●	–	–	–	–	●	–	–
Peripheral ICs	●	●	●	●	●	●	–	●	●	●
Opto-Electronic Devices	●	–	–	–	–	●	–	–	●	–
Capacitors	●	●	●	●	●	●	●	●	●	●
Fluorescent Indicator Panels	–	–	–	–	–	–	–	–	–	–
CRTs	–	–	–	–	–	–	–	–	–	–
Linear ICs for Car Audio	–	–	–	–	–	–	–	–	–	–
Digital Tuning System ICs	–	–	–	–	–	–	–	–	–	–
	Power Train									

	⑪ Voice Warning and Recognition	⑫ Time Control	⑬ Trip Control	⑭ Lighting Control	⑮ Electronic Navigation/Trip Computer	⑯ Turn Signals	⑰ Windshield Wiper/Washer	⑱ Fuel Meter	⑲ Clock	⑳ Speedometer	㉑ Tachometer
Transistors/MOS FETs	●	●	●	●	●	●	●	●	●	●	●
Diodes	●	●	●	●	●	●	●	●	●	●	●
Linear ICs, Digital ICs, G/A	●	●	●	●	●	●	●	●	●	●	●
16-, 8-bit Microcomputers	●	–	●	–	●	–	–	–	–	–	–
4-bit Microcomputers	–	–	●	●	–	–	–	●	●	●	●
Peripheral ICs	●	●	●	●	●	–	–	–	●	–	–
Opto-Electronic Devices	–	–	–	●	●	–	–	●	●	●	●
Capacitors	●	●	●	●	●	●	●	●	●	●	●
Fluorescent Indicator Panels	–	–	–	–	–	–	–	●	●	●	●
CRTs	–	–	–	–	●	–	–	●	●	●	●
Linear ICs for Car Audio	–	–	–	–	–	–	–	–	–	–	–
Digital Tuning System ICs	–	–	–	–	–	–	–	–	–	–	–
	Instruments										

	㉒ Digitally Tuned Radio	㉓ Car Radio and Car Stereo	㉔ Coolant Temperature Meter	㉕ Safety and Malfunction Monitoring System	㉖ Air-Bag Activation System	㉗ Vehicle Collision Prevention System	㉘ Anti-Skid Control System	㉙ Auto Door-Lock Control System	㉚ Seat-Belt Control System	㉛ Automatic Suspension Control System	㉜ Air-Conditioning Control System
Transistors/MOS FETs	●	●	●	●	●	●	●	●	●	●	●
Diodes	●	●	●	●	●	●	●	●	●	●	●
Linear ICs, Digital ICs, G/A	●	●	●	●	●	●	●	●	●	●	●
16-, 8-bit Microcomputers	–	–	●	●	●	●	●	–	–	–	●
4-bit Microcomputers	–	●	●	●	–	–	–	●	●	●	●
Peripheral ICs	–	–	●	●	●	●	●	●	●	●	●
Opto-Electronic Devices	●	●	●	●	–	–	–	–	–	●	●
Capacitors	●	●	●	●	●	●	●	●	●	●	●
Fluorescent Indicator Panels	●	●	●	●	–	–	–	–	–	–	–
CRTs	–	–	●	●	–	–	–	–	–	–	–
Linear ICs for Car Audio	●	●	–	–	–	–	–	–	–	–	–
Digital Tuning System ICs	●	●	–	–	–	–	–	–	–	–	–
	Safety/Environmental										



1 AM Stereo/FM Stereo CD with Equalizer
2 Steering Wheel-Mounted Accessory Controls
3 Modular Speaker Systems
3A Speakers

4 Powertrain Controls
5 Engine Controls
6 Suspension Controls
7 Electronic Spark Control-Knock
8 Supplemental Inflatable Restraint Dual Sensor
9 Supplemental Inflatable Restraint Forward Sensor
10 PASS Key
11 Multiplex Control Modules
12 Electronic Variable Power Steering
13 Near Obstacle Detection
14 Anti-Lock Brake System
15 Ignition Control Module
16 Voltage Regulator
17 Pressure Sensors
18 Supplemental Inflatable Restraint-Electronics
19 Body Computer Module
20 Universal Theft Deterrent II
21 E-Key

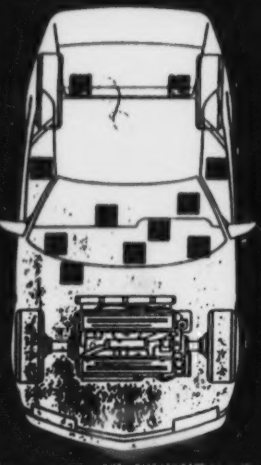
22 Reconfigurable Display System & Controller
23 Head Up Display
24 Digital Information Center
25 Hybrid Instrument Cluster
26 Electronic Air Control
27 Passenger Climate Control
28 Electronic Air Control Programmer

Delco Electronics
Subsidiary of GM Hughes Electronics

It's who we are.

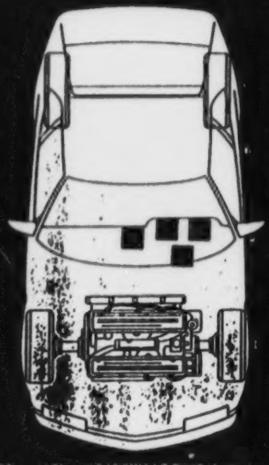
AUDIO SYSTEMS AND HEATER/AIR ELECTRONICS

Delco/Bose Music Systems
Electronically Tuned Receivers
Compact Disc Players
Steering Wheel Radio Controls
Van and RV Music Systems
Heater/Air Controls



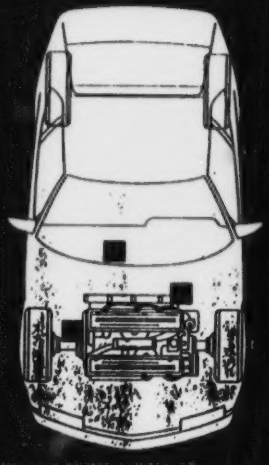
INSTRUMENTATION AND DISPLAY ELECTRONICS

Instrument Clusters
Auxiliary Displays
Head-Up Displays
Other Emerging Display
  Technologies



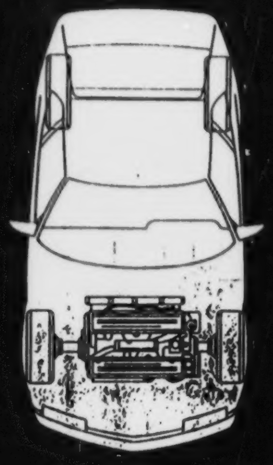
POWERTRAIN ELECTRONICS

Multi Function Engine Controls
Base Function Engine Controls
Engine/Transmission Controls
Spark Timing Controls
Heavy Duty Vehicle Controls



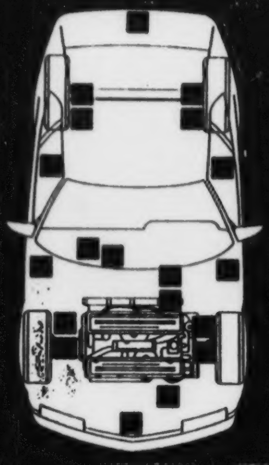
BODY ELECTRONICS

Body Computer Modules
Inflatable Restraint Electronics
CRT Controller
Near Obstacle Detection
Electronic Key
Navigation Systems
Multiplex Switching



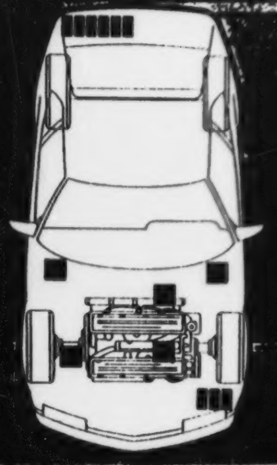
CHASSIS ELECTRONICS

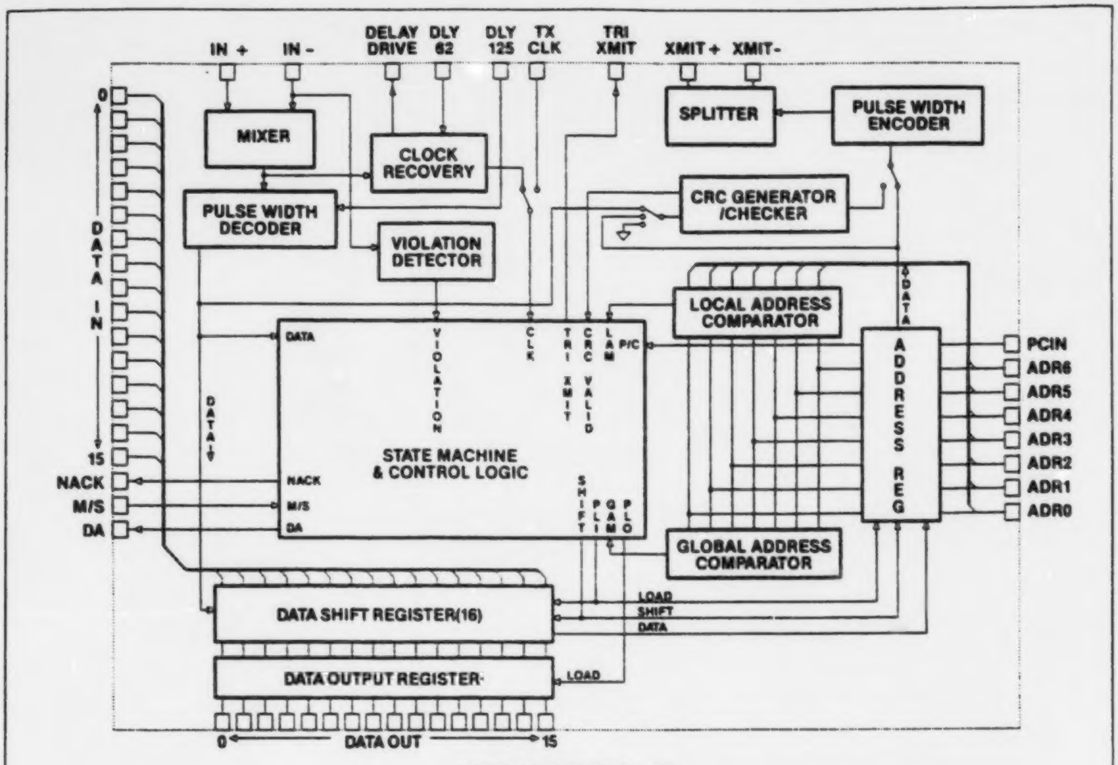
Theft Deterrent Systems
Anti-Lock Brake & Traction
  Control
Power Steering Controller
Suspension and Ride Control



INTEGRATED CIRCUITS AND HYBRID ELECTRONICS

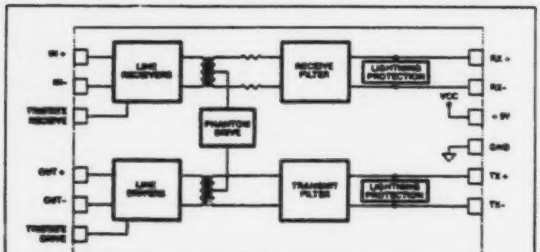
IC Fabrication
Ignition Modules
Voltage Regulators
Electronic Spark Controls
Pressure Sensors
Multiplex Control Modules




IN +
IN -
DELAY DRIVE
DLY 62
DLY 125
TX CLK
TRI XMIT
XMIT +
XMIT -
0
DATA IN
15
NACK
M/S
DA
MIXER
CLOCK RECOVERY
PULSE WIDTH DECODER
VIOLATION DETECTOR
SPLITTER
PULSE WIDTH ENCODER
CRC GENERATOR /CHECKER
LOCAL ADDRESS COMPARATOR
GLOBAL ADDRESS COMPARATOR
ADDRESS REG
DATA
STATE MACHINE & CONTROL LOGIC
VIOLATION
CLK
TRI XMIT
CRC VALID
LAM
P/C
SHIFT
PLI
GAM
PLO
PCIN
ADR6
ADR5
ADR4
ADR3
ADR2
ADR1
ADR0
DATA SHIFT REGISTER(16)
DATA OUTPUT REGISTER
LOAD
SHIFT
DATA
LOAD
0
DATA OUT
15

AUTOLAN CONTROLLER

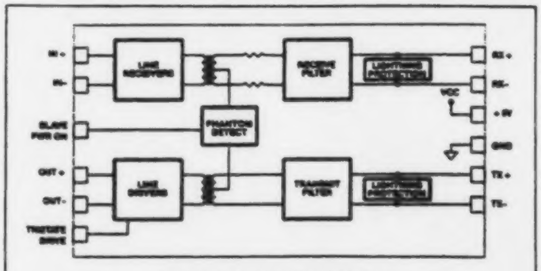
LINE INTERFACE MODULES—Different Line Interface Modules are used for Master and Slave nodes.


IN +
IN -
TRISTATE RECEIVE
OUT +
OUT -
TRISTATE DRIVE
LINE RECEIVERS
PHANTOM DRIVE
LINE DRIVERS
RECEIVE FILTER
TRANSMIT FILTER
LIGHTNING PROTECTION
LIGHTNING PROTECTION
RX +
RX -
VCC
+5V
GND
TX +
TX -

MASTER LINE INTERFACE

Both modules contain the analog line drivers and receiver ICs, the line transformers, EMC filters, and lightning protection devices.

The input and output impedances are different for each module. The Slave module both drives and receives at taps on a 'party line.' The Master module drives and receives at one end of a line and is required to match the line characteristic impedance.


IN +
IN -
SLAVE PWR ON
OUT +
OUT -
TRISTATE DRIVE
LINE RECEIVERS
PHANTOM DETECT
LINE DRIVERS
RECEIVE FILTER
TRANSMIT FILTER
LIGHTNING PROTECTION
LIGHTNING PROTECTION
RX +
RX -
VCC
+5V
GND
TX +
TX -

SLAVE LINE INTERFACE

APPENDIX D

AUTOMOTIVE ELECTRONICS
SAMPLE SPECIFICATIONS

APPENDIX D

AUTOMOTIVE ELECTRONICS

* Sample Specifications *

Chrysler Motors' Electronic Engine Controller

Specifications - The Engine Controller is required to function over the following environmental conditions:

- ambient air temperature: from -40°C to +105°C
- thermal shock for 50 cycles of: soak at - 40°C for 90min -> transition to +105°C in 30s -> soak at +105°C for 90min -> transition to - 40°C in 30s
- random vibration: 10min vibration while sweeping from 20Hz to 80Hz at +3dB/Octave, from 80Hz to 350Hz at 0.04g*g/Hz and 350Hz to 2000Hz at -3dB/Octave
- salt spray: 24h exposure to 5% salt spray at 35°C
- reverse battery jump: 5min at -24 V
- load dump: simulated alternator inductive load dump
- repetitive battery cable disconnects while engine running (operation from alternator only)
- long term thermal cycle durability; 9 weeks with weekly changeover from hot cycle to cold cycle as follows:
  - hot cycle: 30min soak at 25°C -> 1.5h ramp to 105°C -> no operation for 30min -> operation for 2.5h -> 2h ramp down to 0°C -> 3.5h operation -> 30min ramp to 25°C -> 30 min operation
  - cold cycle: 30min operation at 25°C -> 1.5h ramp to -40°C -> no operation for 30min -> operation for 2.5h -> 2h ramp to 35°C -> 1h ramp to 98% RH -> 1h operation at 98% RH and 35°C -> 30min RH ramp down to 0% while not operating -> 1h operation at 35°C 0% RH -> 30min ramp down to 25°C.

Bendix Anti-Lock Control Module

During state 1, the computer's analysis sub-routine compares the calculated wheel speed to a predetermined decay threshold. If the wheel speed drops below the threshold a "decay" command will be sent to the valve action sub-routine. The decay threshold is composed of three components; these are slip, fix and adjust. Slip is the difference between wheel speed and vehicle speed. Fix is calculated on the tire/road coefficient-of-friction, the status of the other wheel control channels and the amount of time spent in this pressure build cycle. Adjust is calculated on the performance of recent anti-lock cycles and provides a mean of zeroing in on the present tire/road friction braking capability.

In state 2, the wheel is decelerating and the brake pressure is being bled off. When the rate-of-change of deceleration or "jerk" changes polarity to a positive value, a "hold pressure" command is sent to the valve action sub-routine.

In state 3, the wheel is accelerating and the brake pressure is being bled off. The decision to initiate a "fast build" or a "slow build" command is determined in this portion of the analysis sub-routine. Wheel slip is compared to slip thresholds to make this determination.

During state 4, the wheel is accelerating and the brake pressure is building. This portion of the software determines the build rates. Changes between "fast build" and "slow build" or a transition back to state 3 can be determined.

The valve action sub-routine controls the valve duty cycles and interprets the valve commands from the analysis software routines. There are ten hydraulic solenoid valves being controlled. These are left front decay, right front decay, rear decay, left front build, right front build, rear build, left front isolate, right front isolate, left rear isolate and right rear isolate.

While all of the above is happening, the watch-dog COPS-640 micro-computer is monitoring the actions of the MCS-8096 micro-computer and can reset it if necessary. A red warning light is activated if a brake system malfunction is detected.

The system can be interrogated by diagnostic commands transmitted from a data readout box over a serial data link. It is interesting to note that even an elaborate software part number can be retrieved from the module's program memory through the data link.

Specifications - The Chrysler performance standard for the Bendix Anti-Lock control module requires the following :

- normal operation at temperatures of -40°C to +105°C
- normal operation per specifications over the operating voltage range of +9 VDC to +16 VDC
- sustained Dynamic Burn-In of 1000 hours at +105°C
- thermal shock: five cycles of the following: two hour soak at 105°C -> ramp to -40°C in 2min -> two hour soak at -40°C -> ramp to +105°C in 2min
- survive 95% relative humidity at 37°C for 240 consecutive hours while powered at 14.5 VDC
- survive salt spray per ASTM B117 for 96 consecutive hours
- survive salt water immersion to a depth of 3.5 ft for 5h
- survive pseudo-random vibration for 15min in each of three orthogonal axes sequentially, one of which is normal to the plane of the printed circuit board, in accordance with the following Power Spectral Density:
  - from 20 Hz to 80 Hz, PSD is to have slope of +3 dB/Octave multiplied by g*g/Hz
  - from 80 Hz to 350 Hz, PSD is a constant 0.04*g*g/Hz
  - from 350 Hz to 2000 Hz, PSD is to have a slope of -3 dB/Octave multiplied by g*g/Hz
- survive overvoltage of +24VDC for 30s; survive overvoltage of +20VDC for 1h
- survive reverse voltage of -16VDC for 5min
- survive inductive load dump voltage transients in accordance with SAE J1113, June 1984, paragraph 4, test pulse 5 (Vs=80 V, T= 400 ms, open circuit); if the pulse generator has an internal source impedance of 1 ohm or less the module must survive 20 pulses applied 2min apart; if the pulse generator source impedance is equal to 2 ohms then the module must survive 100 pulses applied 30s apart
- function with low voltage dips to 7 volts and drop-outs to zero volts for up to 100ms without failure
- survive electro-static-discharges of 4 kV and 15 kV
- pass the following **EMI/RFI stress**
  - magnetic field susceptibility
    - perform test per SAE J1113, June 84, paragraph 6 (frequency range modified to: 60 Hz to 30 kHz); the magnetic field intensity at 60 Hz shall be 160 dB above 1 picotesla decreasing at a rate of 12 dB per octave

- electromagnetic field susceptibility
  - perform test per SAE J1113, June 84, paragraphs 7 and 8 (14 kHz to 1 GHz); the field strength to be a minimum of 100V per metre
- conducted susceptibility
  - perform test per SAE J1113, June 1984, paragraph 4
- direct radio frequency power
  - the unit shall not be damaged nor fail to function normally when subjected to 5W of RF over the frequency range of 250 kHz to 250 MHz injected through a 10 dB attenuator
- radiated RF noise from the module
  - must be below 0.56 microvolts at the car antenna from 535 kHz to 1605 kHz
  - must be below 0.7 microvolts at the car antenna from 89.7 MHz to 107.9 MHz
  - must be below 0.25 µV at a 1/4 wavelength antenna mounted in the rear or roof from 1800kHz to 1.3GHz.

Oldsmobile Driver Information System

Physical Environmental Requirements (non-operating) - The General Motors' Buick/Oldsmobile/Cadillac engineering department requires that the Driver Information System meet the following environmental specifications:

- thermal shock -40°C to +85°C for at least 48 cycles of:
    - soak 25min at +85°C
    - transition to -40°C in less than 5min
    - soak 25min at -40°C
    - transition to +85°C in less than 5min
- survive 10 cycles of 95% relative humidity testing at +38°C to +85°C
    - soak 6h at +85°C with 95% RH
    - transition to +38°C in 16h maintaining 95% RH
    - transition to +85°C in 2h maintaining 95% RH
- survive vibration testing immediately after cold and hot soaks; for each of the three axes
    - soak at -40°C for 2h
    - vibrate 30min at a 0.8 mm peak-to-peak amplitude while sweeping from 10 Hz to 100 Hz at 10 Hz per minute
    - repeat the above with soaks at +85°C instead of -40°C
- survive high temperature storage
    - check all electrical performance characteristics after stabilizing at +25°C
    - store at +85°C for 168h
    - check all electrical performance characteristics after stabilizing at +25°C
    - store at +85°C for another 336h
    - check all electrical performance characteristics after stabilizing at +25°C

Physical Environmental Requirements (operating)

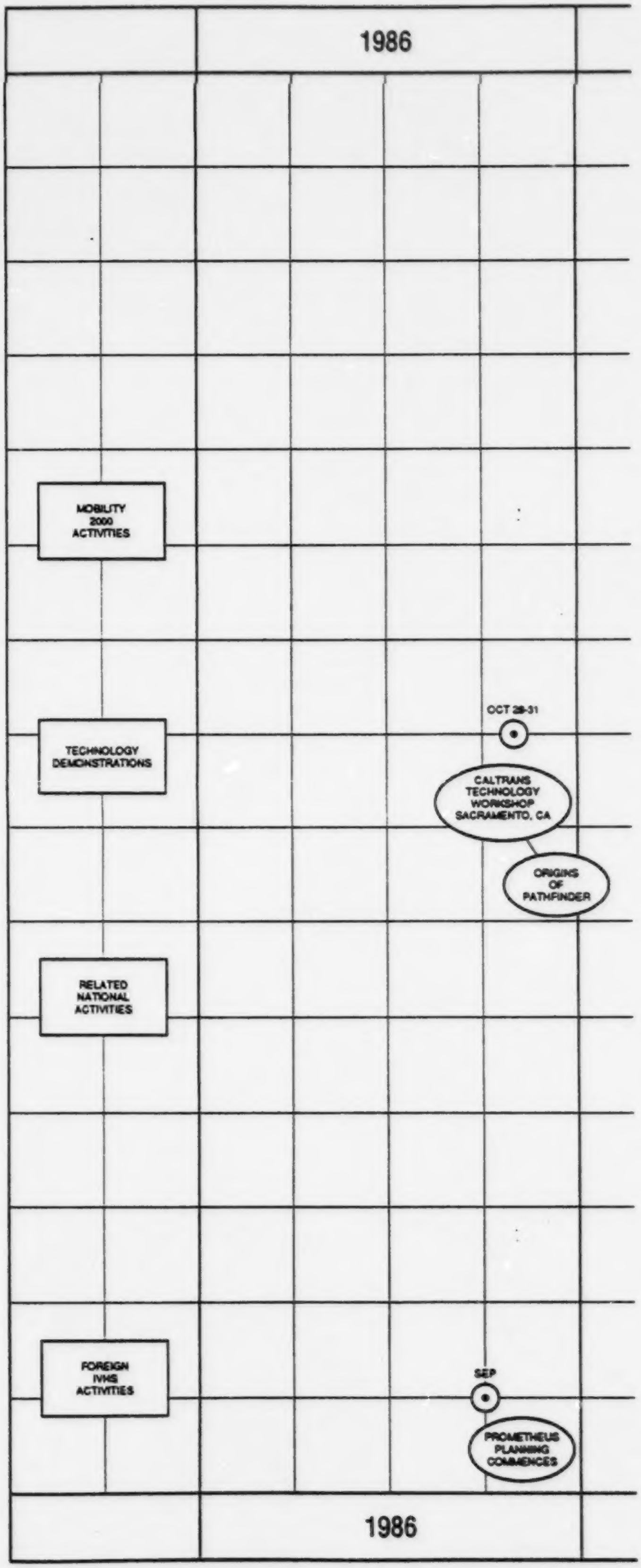
- perform all electrical functions normally while enduring 1825 thermal cycles from -40°C to +85°C.

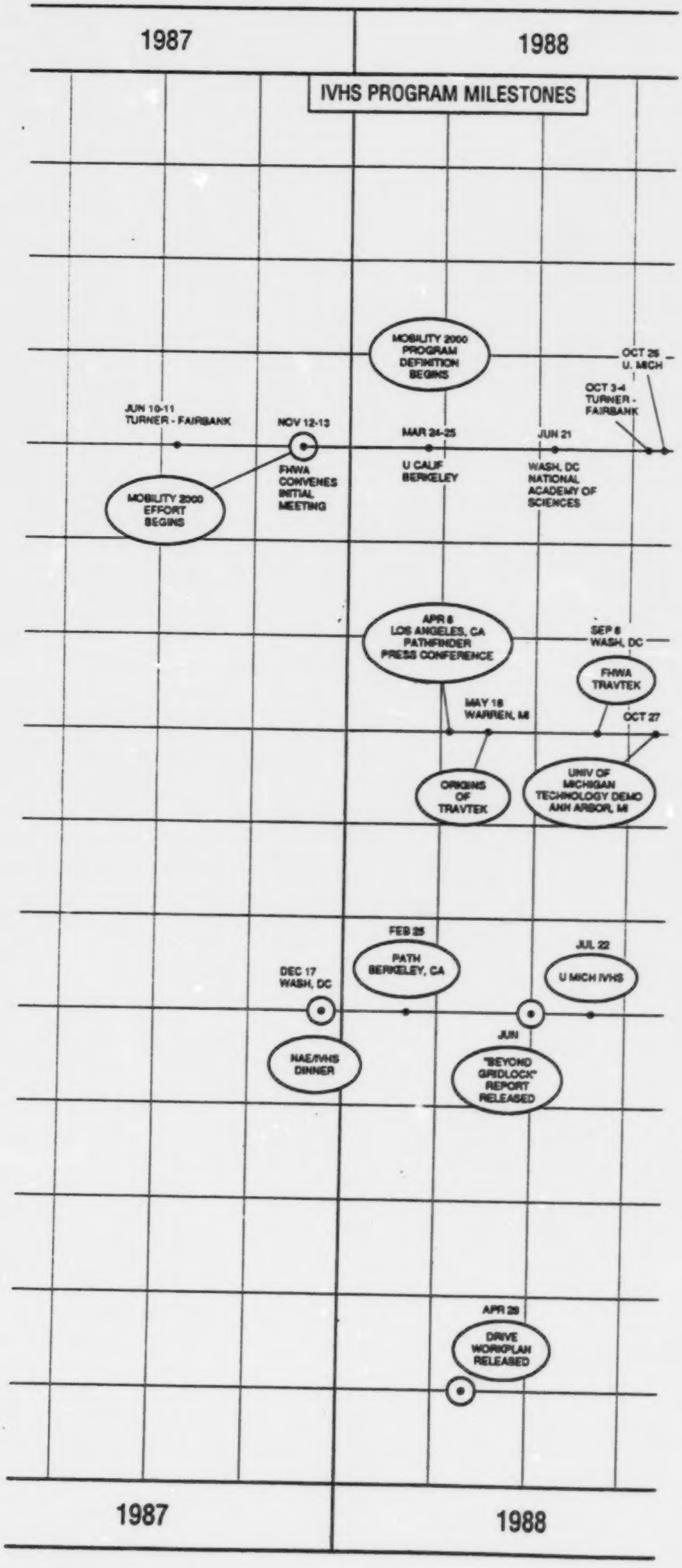
APPENDIX E

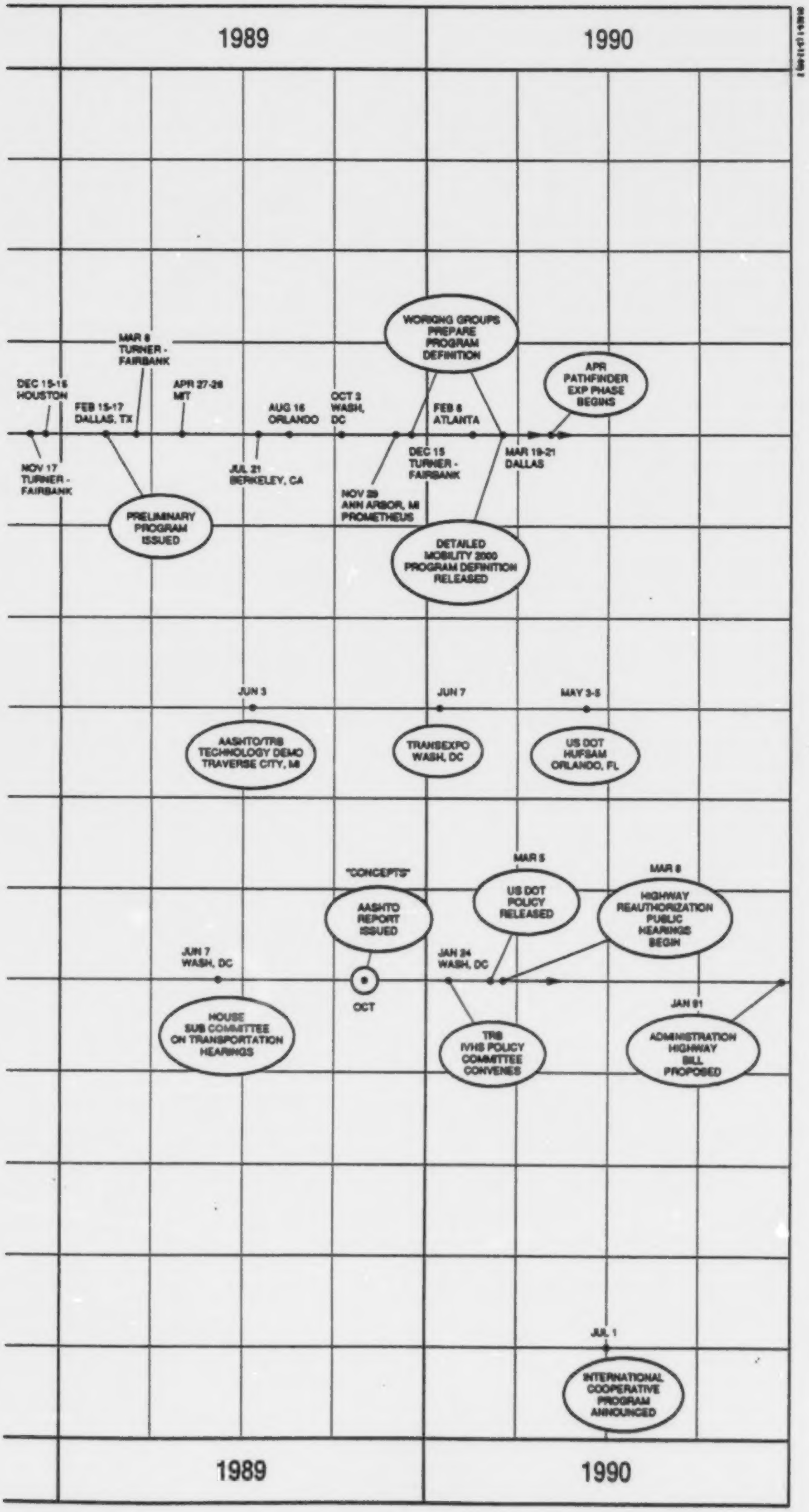
UNITED STATES IVHS PROGRAM

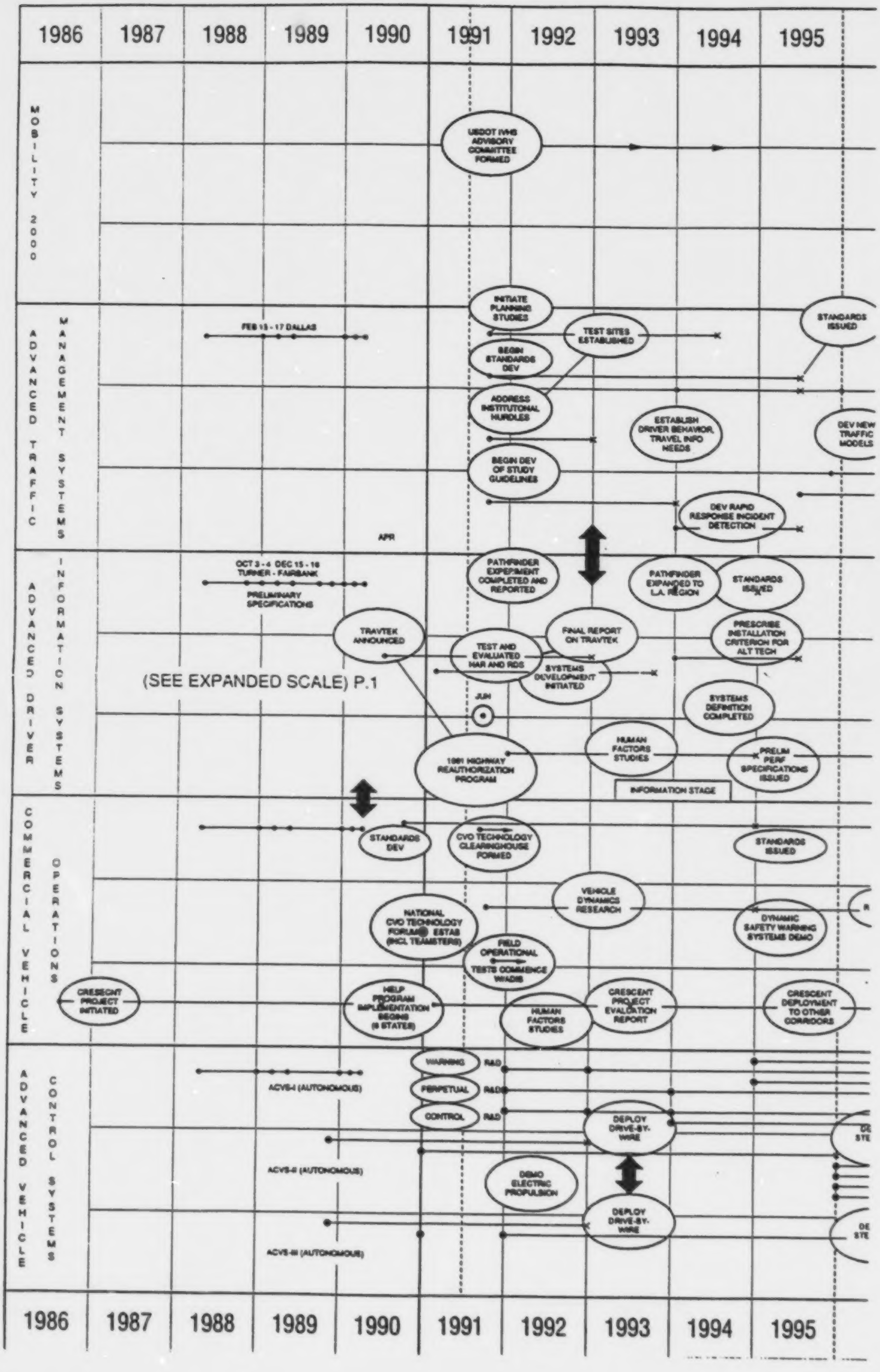
SUGGESTED MILESTONES

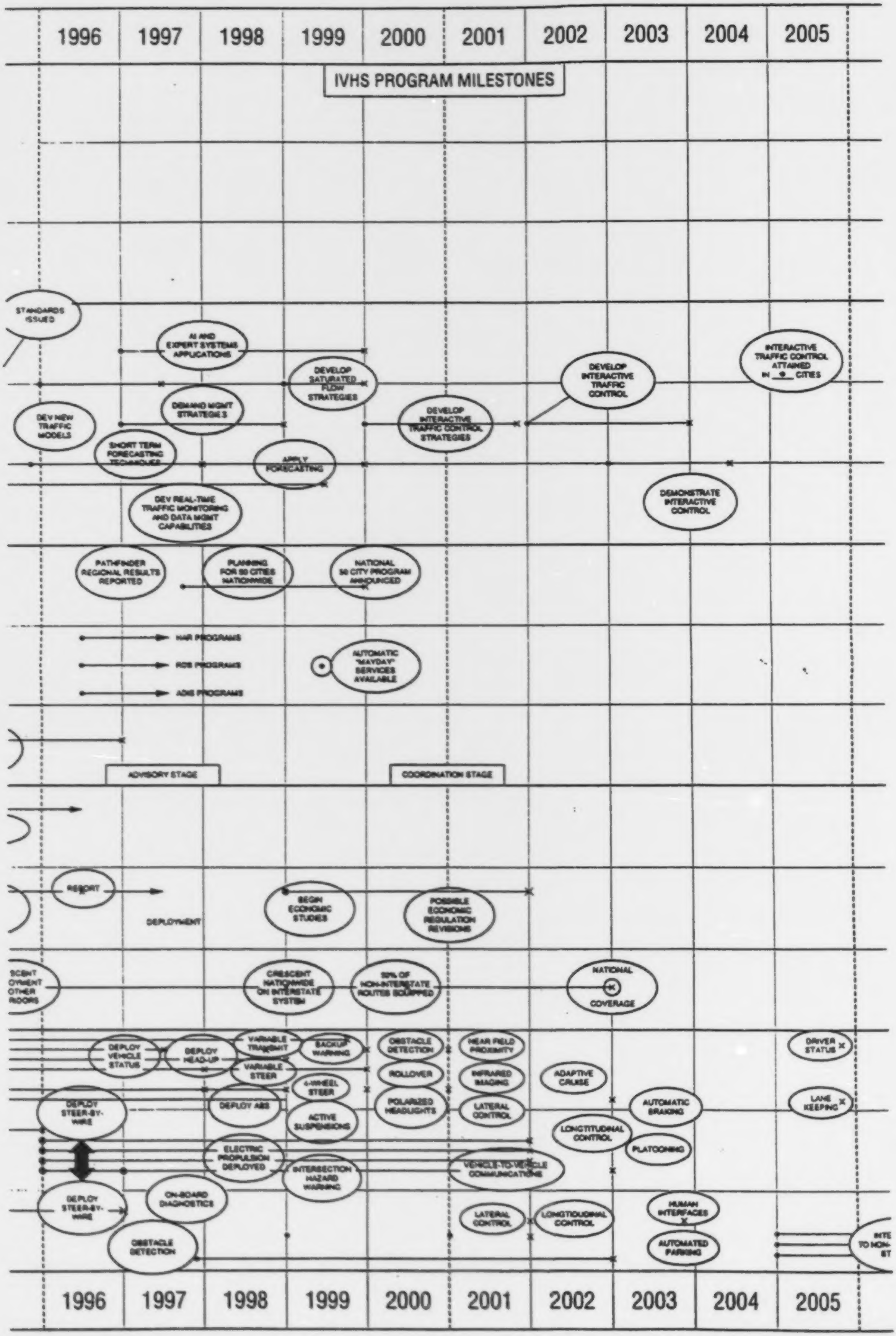
(MOBILITY 2000 WORKSHOP * 19-21 MARCH 1990)

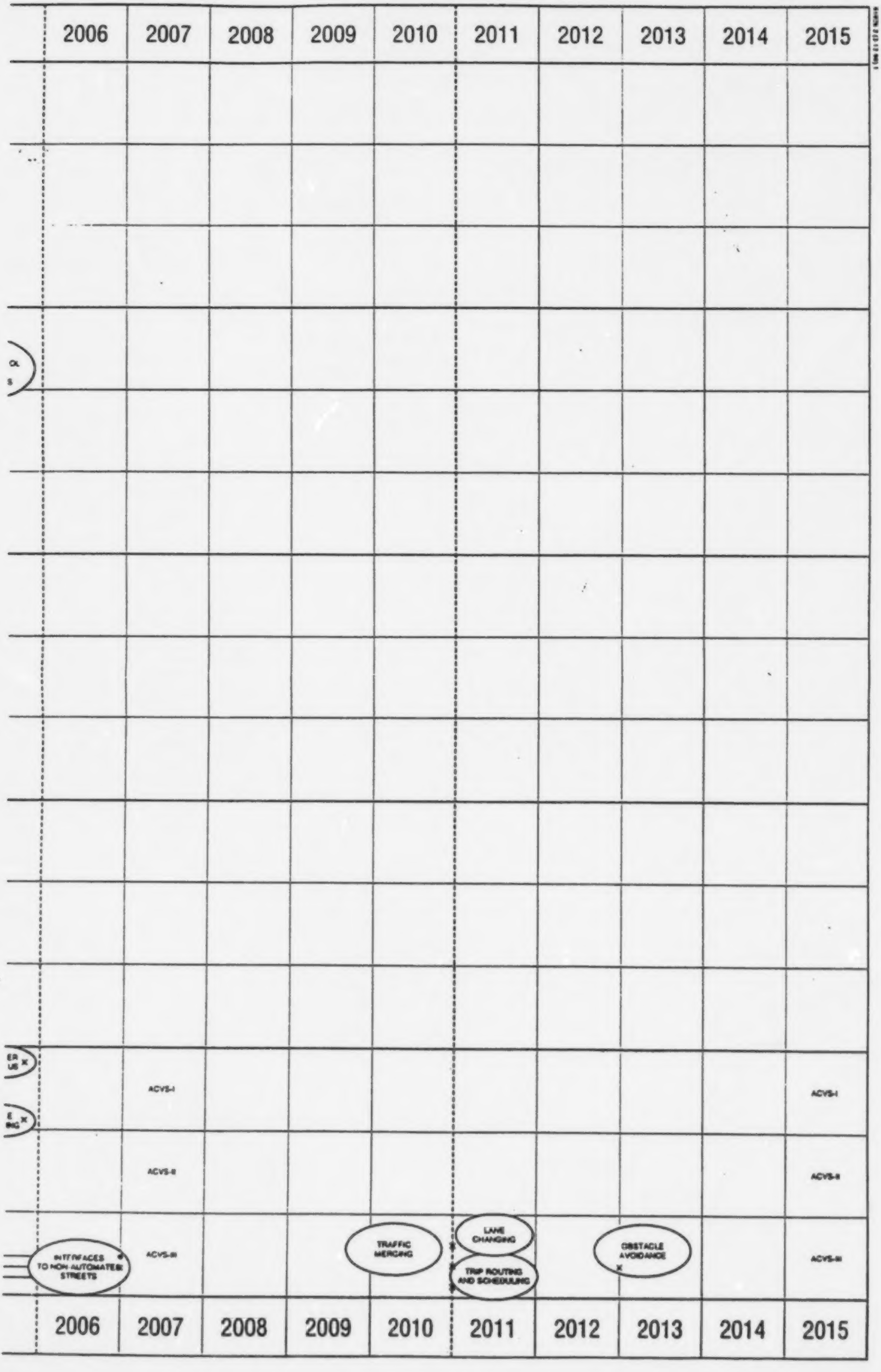

1986
MOBILITY 2000 ACTIVITIES
TECHNOLOGY DEMONSTRATIONS
OCT 29-31
CALTRANS TECHNOLOGY WORKSHOP SACRAMENTO, CA
ORIGINS OF PATHFINDER
RELATED NATIONAL ACTIVITIES
FOREIGN IVHS ACTIVITIES
SEP
PROMETHEUS PLANNING COMMENCES
1986


1987
1988
IVHS PROGRAM MILESTONES
MOBILITY 2000 PROGRAM DEFINITION BEGINS
OCT 25 U. MICH
OCT 3-4 TURNER - FAIRBANK
JUN 10-11 TURNER - FAIRBANK
NOV 12-13
MAR 24-25
JUN 21
FHWA CONVENES INITIAL MEETING
U CALIF BERKELEY
WASH, DC NATIONAL ACADEMY OF SCIENCES
MOBILITY 2000 EFFORT BEGINS
APR 8 LOS ANGELES, CA PATHFINDER PRESS CONFERENCE
SEP 8 WASH, DC
FHWA TRAVTEK
MAY 18 WARREN, MI
OCT 27
ORIGINS OF TRAVTEK
UNIV OF MICHIGAN TECHNOLOGY DEMO ANN ARBOR, MI
FEB 25
PATH BERKELEY, CA
JUL 22
U MICH IVHS
DEC 17 WASH, DC
JUN
NAE/IVHS DINNER
"BEYOND GRIDLOCK" REPORT RELEASED
APR 29
DRIVE WORKPLAN RELEASED
1987
1988


1989
1990
DEC 15-16 HOUSTON
NOV 17 TURNER - FAIRBANK
FEB 15-17 DALLAS, TX
MAR 8 TURNER - FAIRBANK
APR 27-28 MIT
PRELIMINARY PROGRAM ISSUED
JUL 21 BERKELEY, CA
AUG 16 ORLANDO
OCT 3 WASH, DC
NOV 29 ANN ARBOR, MI PROMETHEUS
WORKING GROUPS PREPARE PROGRAM DEFINITION
DEC 15 TURNER - FAIRBANK
FEB 8 ATLANTA
MAR 19-21 DALLAS
DETAILED MOBILITY 2000 PROGRAM DEFINITION RELEASED
APR PATHFINDER EXP PHASE BEGINS
JUN 3
AASHTO/TRB TECHNOLOGY DEMO TRAVERSE CITY, MI
JUN 7
TRANSEXPO WASH, DC
MAY 3-5
US DOT HUFSAM ORLANDO, FL
"CONCEPTS"
AASHTO REPORT ISSUED
OCT
JUN 7 WASH, DC
HOUSE SUB COMMITTEE ON TRANSPORTATION HEARINGS
JAN 24 WASH, DC
TRB IVHS POLICY COMMITTEE CONVENES
MAR 5
US DOT POLICY RELEASED
MAR 8
HIGHWAY REAUTHORIZATION PUBLIC HEARINGS BEGIN
JAN 91
ADMINISTRATION HIGHWAY BILL PROPOSED
JUL 1
INTERNATIONAL COOPERATIVE PROGRAM ANNOUNCED
1989
1990

1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
MOBILITY 2000
USDOT IVHS ADVISORY COMMITTEE FORMED
ADVANCED TRAFFIC MANAGEMENT SYSTEMS
FEB 15 - 17 DALLAS
INITIATE PLANNING STUDIES
TEST SITES ESTABLISHED
STANDARDS ISSUED
BEGIN STANDARDS DEV
ADDRESS INSTITUTONAL HURDLES
ESTABLISH DRIVER BEHAVIOR, TRAVEL INFO NEEDS
DEV NEW TRAFFIC MODELS
BEGIN DEV OF STUDY GUIDELINES
DEV RAPID RESPONSE INCIDENT DETECTION
APR
ADVANCED DRIVER INFORMATION SYSTEMS
OCT 3 - 4 DEC 15 - 16
TURNER - FAIRBANK
PRELIMINARY SPECIFICATIONS
PATHFINDER EXPEPIMENT COMPLETED AND REPORTED
PATHFINDER EXPANDED TO L.A. REGION
STANDARDS ISSUED
TRAVTEK ANNOUNCED
FINAL REPORT ON TRAVTEK
TEST AND EVALUATED HAR AND RDS
PRESCRIBE INSTALLATION CRITERION FOR ALT TECH
SYSTEMS DEVELOPMENT INITIATED
(SEE EXPANDED SCALE) P.1
JUN
SYSTEMS DEFINITION COMPLETED
1991 HIGHWAY REAUTHORIZATION PROGRAM
HUMAN FACTORS STUDIES
PRELIM PERF SPECIFICATIONS ISSUED
INFORMATION STAGE
COMMERCIAL VEHICLE OPERATIONS
STANDARDS DEV
CVO TECHNOLOGY CLEARINGHOUSE FORMED
STANDARDS ISSUED
VEHICLE DYNAMICS RESEARCH
NATIONAL CVO TECHNOLOGY FORUM ESTAB (INCL TEAMSTERS)
DYNAMIC SAFETY WARNING SYSTEMS DEMO
FIELD OPERATIONAL TESTS COMMENCE WIADIS
CRESECNT PROJECT INITIATED
HELP PROGRAM IMPLEMENTATION BEGINS (6 STATES)
HUMAN FACTORS STUDIES
CRESCENT PROJECT EVALUATION REPORT
CRESCENT DEPLOYMENT TO OTHER CORRIDORS
ADVANCED VEHICLE CONTROL SYSTEMS
WARNING
R&D
PERPETUAL
R&D
CONTROL
R&D
ACVS-I (AUTONOMOUS)
DEPLOY DRIVE-BY-WIRE
ACVS-II (AUTONOMOUS)
DEMO ELECTRIC PROPULSION
DEPLOY DRIVE-BY-WIRE
ACVS-III (AUTONOMOUS)
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995


1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
IVHS PROGRAM MILESTONES
STANDARDS ISSUED
AI AND EXPERT SYSTEMS APPLICATIONS
DEVELOP SATURATED FLOW STRATEGIES
DEVELOP INTERACTIVE TRAFFIC CONTROL
INTERACTIVE TRAFFIC CONTROL ATTAINED IN __ CITIES
DEMAND MGMT STRATEGIES
DEV NEW TRAFFIC MODELS
DEVELOP INTERACTIVE TRAFFIC CONTROL STRATEGIES
SHORT TERM FORECASTING TECHNIQUES
APPLY FORECASTING
DEV REAL-TIME TRAFFIC MONITORING AND DATA MGMT CAPABILITIES
DEMONSTRATE INTERACTIVE CONTROL
PATHFINDER REGIONAL RESULTS REPORTED
PLANNING FOR 50 CITIES NATIONWIDE
NATIONAL 50 CITY PROGRAM ANNOUNCED
HAR PROGRAMS
RDS PROGRAMS
ADIS PROGRAMS
AUTOMATIC "MAYDAY" SERVICES AVAILABLE
ADVISORY STAGE
COORDINATION STAGE
REPORT
DEPLOYMENT
BEGIN ECONOMIC STUDIES
POSSIBLE ECONOMIC REGULATION REVISIONS
SCENT OYMENT OTHER RIDORS
CRESCENT NATIONWIDE ON INTERSTATE SYSTEM
50% OF NON-INTERSTATE ROUTES EQUIPPED
NATIONAL COVERAGE
DEPLOY VEHICLE STATUS
DEPLOY HEAD-UP
VARIABLE TRANSMIT
BACKUP WARNING
VARIABLE STEER
OBSTACLE DETECTION
NEAR FIELD PROXIMITY
ROLLOVER
INFRARED IMAGING
ADAPTIVE CRUISE
DRIVER STATUS
4-WHEEL STEER
DEPLOY ABS
ACTIVE SUSPENSIONS
POLARIZED HEADLIGHTS
LATERAL CONTROL
AUTOMATIC BRAKING
LANE KEEPING
DEPLOY STEER-BY-WIRE
LONGTITUDINAL CONTROL
PLATOONING
ELECTRIC PROPULSION DEPLOYED
INTERSECTION HAZARD WARNING
VEHICLE-TO-VEHICLE COMMUNICATIONS
DEPLOY STEER-BY-WIRE
ON-BOARD DIAGNOSTICS
LATERAL CONTROL
LONGTIDUDINAL CONTROL
HUMAN INTERFACES
OBSTACLE DETECTION
AUTOMATED PARKING
INTE TO NON- ST
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005


2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
OL
S
ER
US
E
ING
ACVS-I
ACVS-I
ACVS-II
ACVS-II
INTERFACES TO NON-AUTOMATED STREETS
ACVS-III
TRAFFIC MERGING
LANE CHANGING
TRIP ROUTING AND SCHEDULING
OBSTACLE AVOIDANCE
ACVS-III
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015

APPENDIX B

Plan and Milestones for IVHS: COMMERCIAL VEHICLES

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2005
Crescent Project	Demo in 6 States AVI,WIM,AVC OBC											
Corridor Instrumentation (Crescent Technology)				Demo 3 E/W, 3N/S Truck Corridors		Deployed on 50% of Interstate		Deployed on 50% of National Truck Network		Deployed on 100% of Int. and 50% of National Truck Network		
Weigh In Motion	Deployed selectively in all states			Deployed on 50% of Interstate				Deployed on 100% of Interstate				
Automatic Reporting for Interstate Carriers		Demo Integration of OBC with AVI,AVC,AVL at Crescent sites to meet IRP and fuel tax requirements		Demo multistate reporting in Crescent and Corridor States						Deployed in all states	Deployed in all border Canadian/ Mexican Provinces	
Automatic Toll Collection		Demo at Dulles and TRANSCOM toll sites	Demo in 5 states and 5 urbanized areas			Deployed on all State Tollroads Deployed at 50% of toll tunnels & bridges			Deployed at all major toll facilities open to trucks			
Remote Driver/ Vehicle Inspections		Research OBC/reader/ Out Service Criteria		Demo in 2 contiguous states & 1 other state		Deployed in 25% of states & 2 Canadian Provinces					Deployed in all states	

APPENDIX B - CONTINUED

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2005
Vehicle & Cargo Hazmat Tracking			Research Elec. Bill of Lading/Placard, Stolen Vehicle Tracking	Demo in 1 State	Feasibility for International HM	Deployed in 10 states		Research non-HM cargo tracking			Deployed for HM tracking in all states & major HM shippers	
Electronic Recording Oversize/Weight Permits			Demo in 1 region, link states electronically	Demo in 2 contiguous regions		Deployed in 50% of regions				Deployed in all regions		
CMV Driver In-Vehicle Displays		Research human factors		Demo in urbanized and interstate operation								
CMV Driver Fatigue/cell Monitoring			Research human factors/ driver monitoring		Demo in 1 truck corridor	Disseminate Results						
Vehicle Dynamics		Research/ test stability improvement			Deployment determined by market acceptance							
Proximity Warning Systems		Development by private sector			Deployment determined by market acceptance							
Dynamic Safety Warning Systems, Vehicle and Site Specific including Grade Severity, Ramp Speed, and Sight Distance			Research		Demo: Selected Locations		Disseminate Results					

APPENDIX F

CONTACT LIST

AUTOMATIC VEHICLE IDENTIFICATION

WEIGH-IN-MOTION

AUTOMATIC VEHICLE CLASSIFICATION

AUTOMATIC VEHICLE LOCATION

IMAGE PROCESSING

TRIP PLANNING

AUTOMATIC VEHICLE IDENTIFICATION

AMTECH CORPORATION
4514 Cole Ave, Ste 1200
LB# 28
Dallas, TX 75205
(214) 520-6900
Jim Schmidt
Tom McDaniel, PhD, Vice Pres. Marketing

AMTECH
2530 Camino Entrada
Sante Fe, NM 87505
(505) 473-4482
Ken Strasser, Manager Special Projects
Wiliam Davers, Vice President

AUSTEC
17316-107 Avenue
Edmonton Alberta, T5S 1E9
(403) 486-0511
Fax: (403) 489-3697
Keith Brocklesby, President
Dr. Conrad Walker, Vice President

BOSCH
Robert Bosch Strasse 200
Hildesheim
51-2149 4647
Telex: 927151-0
Dr. Wolf Zechnall,
Abteilungsleiter
Vorentwicklung

CORPORATE STRATEGIES, INC.
5415-A Backlick Road
Springfield, Va. 22151
703-941-0560
Robert H. Leilich

DOWTY ELECTRONICS
281-283 Bedford Road
Kempstone
Bedfordshire, MK42-8QB
0234-852947
Ian McCullagh, Marketing

DOWTY ELECTRONICS
Communications Division
419 Bridport Road
Greenfort, Middlesex
England UB6 8UA
011-44-1-578-0081
P.J. MC Lelland

EMX, INC.
3570 Warrensville Center Road
Shaker Heights, OH 44122
(216) 991-4333
Fax: (216) 464-2980
Joe Rozgonyi, President

EUREKA SYSTEM Inc,
560 Sylvan Avenue
Englwood Cliff, NJ 07632
(201) 567-4337
Fax: (201) 567-4833

GENERAL RAILWAY SIGNAL
P.O. Box 20600
Rochester, NY 14602-0600
(716) 783-2405
Fax: 716-783-2099
Daniel J. Reitz

GEOSTAR CORPORATION
101 Carnegie Center
Suite 302
Princeton, NJ 08540
(609) 452-1130
Dr. Gerard K. O'Neil

IDENTICON CORPORATION
300 Second Avenue
Waltham, MA 02514
(617) 890-6600
Henry White, President

LAZERDATA
2400 Diversified Way
Orlando, Fl 32804
(407) 843-8975
Fax: 407-425-6530

AUTOMATIC VEHICLE IDENTIFICATION

LOCKHEED ELECTRONICS, INC.
Systems Division
2531 Jefferson Davis Highway
Arlington, VA 22202
(703) 979-1111
Donald J. Rowan, Marketing Manager
Robert J. Dalton, Consultant

3M
220-4E 3M Center
St. Paul, MN 55144
(612) 736-2153
Paul Acito

OMNINET
2049 Century Park East,
Suite 3765
Los Angeles, CA 90067
(213) 552-1255

PHILIPS GROUP OF COMPANIES
PREMID SYSTEM
PHILIPS ELECTRONICS
S-175-88 Jarfalla
Sweden
011-46-758-221-41
Stig Rune Johanson

PHILIPS TELECOMMUNICATE EN
INFORMATIE SYSTEMEN BV
Public Transit Systems
Division, MAANWEG 156
2500 BV Den Haag
The Netherlands
011-31 70 762682
Fax: 011-31 70 482102

PLESSEY CONTROLS LTD
Sopers Lane
Poole Dorset GH17 7ER
(0202) 675161
Telex: 41272
Tony Pawley
Brian Watkins, Product Manager,
Traffic Controls
Alan Carter, Export Manager,
Traffic Controls

SARASOTA AUTOMATION
Redland Automation
1500 N. Washington Boulevard
Sarasota, FL 33577
(813) 366-8770
Mike Weeks

SCIENCE APPLICATIONS
INTERNATIONAL CORPORATION
Automatic Identification Systems
Division
10401 Roselle Street
San Diego, CA 92121
(619) 458-4783
Richard Doering

SIEMENS AG
Factory Automation Systems Div.
P.O. Box 3240
D-8520 Erlangen
West Germany
(091) 3172 3761

TRANSCONTROL CORPORATION
320 Oser Ave.
Hauppauge, NY 11788
(516) 231-4180
Telex: 645117
Robert John, Vice President
Marketing

VAPOR CORPORATION
6420 W. Howard Street
Chicago, Il 60648
(312) 470-7800
Fax: 312-632-9200
Mike Wenninger

X-Cyte, Inc.
3800 N. Wilke Road, Suite 300
Arlington Heights, IL 60004
(312) 255-9339
Fax: (312) 259-5412
Rob Chanko

VAPOR CANADA INC
10655 Henri Bourassa West
Montreal, Quebec
Canada H4S 1A1
(514) 335-4214
Kelly P Gravelle

WEIGH-IN-MOTION

AVIAR, INC.
P.O. Box 162184
Austin, Tex 78716
(512) 327-9439
Ronald P. White

BRIDGE WEIGHING SYSTEMS
University Circle Research
Center
11000 Cedar Road
Cleveland, OH 44106
(216) 229-8400
Richard Snyder

CAPITAL ENTERPRISES AND
ENGINEERING
1230-20th Street SE
P.O. Box 12688
Salem, OR 97309

CMI - DEARBORN
820 Lafayette Road
Building #1, Suite 203
Hampton, NH 03842
(603) 926-1200
Jeffrey Davies, Marketing Manager

DATA DYNAMICS
B6 5660 McAdam Road
Mississauga, Ontario,
Canada L4Z 1T2
(416) 890-0797
Brian Taylor

DYNEC CORPORATION
P.O. Box 15123
Austin, TX 78761

ELECTROMATIC (Pty) lTD
P.O. Box 1252
Pietermaritzburg
Natal South Africa 3200
27-331 53339
Fax: 27-331-946449
Cyril Farrow, Senior Marketing
Executive

ELECTRONIQUE CONTROLE MESURE
RUE DU BOIS CHENE LE LOUP
Pole Technologuiques De Brobois
54-5000 Vandoeuure-Les Nancy,
France

EMX CORPORATION
1120 Connecticut Avenue, NW
Washington, DC 20036
(202) 452-8811
George Pagonis

G.K. INSTRUMENTS LTD.
Stevens House, Simpson Road,
Fenny Stratford, Milton Keynes
Buckinghamshire, England
(011) 0908 75742
Georff Kent

G.K. INSTRUMENTS LTD.
15212 Race Track Road
Tampa, Florida 33626
(813) 855-6556

GOLDEN RIVER CORPORATION
7672 Standish Place
Rockville, MD 20855
(301) 340-6800
Fax: (202) 294-0473
Walter O'Connell

GOLDEN RIVER LTD.
Churchill Road
Bicester
Oxfordshire OX6 7XT
0869-246858
Mike Dalgleish, Managing
Director

HOWE RICHARDSON
155 Wicks Street
Grayslake, Ilinois 60030-4550
(312) 223-4801
Gene Beezley

INTERNATIONAL ROAD DYNAMICS INC.
702 43rd St East
Saskatoon, Saskatchewan
Canada S7K 3T9
(306) 934-6777
Terry Bergan

NORTHWEST SIGNAL SUPPLY
Jon Meusch
17410 SW 63rd Ave.
Cake Oswego, OR 97035

WEIGHT-IN-MOTION

PAT EQUIPMENT CORP.
1661 Worcester Rd., Suite 300
Framingham, MA 01701
(617) 872-8211
Joe Madek, Vice President

PRECISION LOADS LTD
Craven House
Carleton New Road
Skipton
North Yorkshire BD23 2DE
(0756) 69475
Telex: 51311

SAFETY SIGNAL SYSTEMS
Rod Norman
7002-220 # Street SW
Mountlake Terrace, WA 98043

SARASOTA AUTOMATION INC.
1500 North Washington Boulevard
Sarasota, Florida 34237
(813) 366-8770
Mr. Derek O'Garr

TOLEDO SCALE COMPANY
350 West Wilson Bridge Road
Worthington, Ohio 43085
(614) 438-4700
Donivan L. Hall

WEIGHWRITE LIMITED
49 West Street
Farnham Surrey
England
011-44-252-711011
Len Gorman

AUTOMATIC VEHICLE CLASSIFICATION

CMI - DEARBORN
820 Lafayette Road
Building #1, Suite 203
Hampton, NH 03842
(603) 926-1200
Jeffrey Davies, Marketing Manager

DIAMOND COUNTERS
Box 691
Oakridge, Or 97463
(503) 782-3903
Guy Gibson

GEC Traffic Automation Ltd.
Elstree Way
BOREHAMWOOD
Hertfordshire, WDG 1RX
England
011-44-195-66786
Fax: 011-44195-35362
J.K. Beadsmore

GK INSTRUMENTS LTD.
Simpson Road
Fenny Stratford
Milton Keynes, MK1-1LN
England
011-44-908-75742
Geoff Kent

GK INSTRUMENTS LTD.
15212 Race Track Road
Tampa, FLorida 33626
(816) 855-6556

GOLDEN RIVER CORPORATION
7672 Standish Place
Rockville, MD 20855
(301) 340-6800
Fax: (202) 294-0473
Walter O'Connell

GOLDEN RIVER LTD.
Churchill Road
Bicester
Oxfordshire OX6 7XT
0869-246858
Fax: 0869-246858
Mike Dalgleish, Managing Director

INTERNATIONAL ROAD DYNAMICS
A5-116-103rd St.
Saskatoon, Saskatchewan
Canada 57N 1Y7
(306) 955-3626
Telex: 0742432
Art Bergen

NEDERLANDSE PHILIPS
BEDRYVEN B.V.
P.O.Box 218
Bldg SK3
5600 MD-Eindhoven
Tel: NL-0Y0-736998
Fax: 037-40737131
Telex: 35000 PHTC NL/NLSEVA
J. Mauge

ROBERT-BOSCH-STR.200
D-3200 HILDESHEIM
Tel: +49-5121-494864
Fax: +49-5121-494054
Ralf Duckelk
Robert Bosch GMBH

SARASOTA AUTOMATION
1500 N. Washington Blvd.
Sarasota, FL 33577
(813) 366-8770
Telex: 803701
Fax: (813) 365-0837
Mike Weeks
Bill Buck

STREETER - RICHARDSON
155 Wicks St.
Grayslake, IL 60030
(312) 223-4801
Susan Smith

AUTOMATIC VEHICLE LOCATION

GEC TRAFFIC AUTOMATION LTD.
Stirling Way, Boreham Wood
Hertfordshire, UK WD6 2AU
Tel: 01-207-3222
Fax: 01-953-5262
Derek Palmer

HUGHES NETWORK SYSTEMS
11717 Exploration Lane
Germantown, MD 20874
(301) 428-5500

II MORROW INC.
2345 Turner Rd. S.E.
P.O. Box 13549
Salem, OR 97309
(503) 581-8101
Fax: (503) 364-2138

MOTOROLA
7230 Parkway Drive
Parkway Center
Hanover, MD 21076
(301) 796-6528
Todd Meredith

QUALCOMM
10555 Sorrento Valley Rd.
San Diego, CA 92121
(619) 587-1121
Fax: 619-452-9096

RAILSTAR
7 Executive Park Drive
Merrimack, NH 03054
(603) 429-1612
Fax: 603-429-1755
Mark Kramer

SONY INFORMATION SYSTEM CO.
Sony Drive
Park Ridge, NJ 07656
(201) 930-6136

SPECTRUM CELLULAR CORP.
2710 Stemmons Freeway
800 North Tower
Dallas, TX 75207
(214) 630-9825

IMAGE PROCESSING SYSTEM

CMR ELECTRONICS LIMITED
Nostell Road
Scunthorpe
South Humberside
DN16 1DL, England
Tel: 0724-856601
Fax: 6724-863423
T. Hoyle

COMPUTER RECOGNITION SYSTEM LTD.
The Business Centre
Wokingham, Bershire, England
Tel: 0734-792077
Fax: 0734-774734

INTEGRATED PHOTOMATRIX LIMITED
The Grove Trading Estate
Dorchester, Dorset DTI ISY,
England
Tel: 0305-63673
Fax: 0305-63679

3M Traffic Control Materials
Division
220-4E-01 3M Center
St. Paul, MN 55105

PERCEPTICS
Pellissippi Center
Knoxville, TN 37922
(615) 966-9200
Fax: (615) 966-9330
W.T. Swain

TRIP PLANNING SYSTEM

ETAK
1455 Adams Drive
Menlo Park, CA 94025

MOBILE DATA INTERNATIONAL
11411 Number Five Road
Richmond B.C. Canada V7A 423
Tel: 604-277-1511
800-678-7MDI

APPENDIX G

CANADIAN AVI AND WIM EQUIPMENT

SAMPLE SPECIFICATIONS

SYSTEM DESCRIPTION

There are two ROADCHECK installation configurations available: in-pavement antennas and overhead antennas.

In-pavement antenna installation

In this configuration, ROADCHECK employs an under-vehicle reading technique. Vapor's unique in-pavement antenna provides complete lane coverage with very little overlap between lanes thus permitting lane identification.

Transponders may be mounted anywhere under the vehicle as long as they are a minimum of 150mm (6 inches) from the ground and have a clear downward view of the road surface. The transponder can be attached to a license plate without obscuring it.

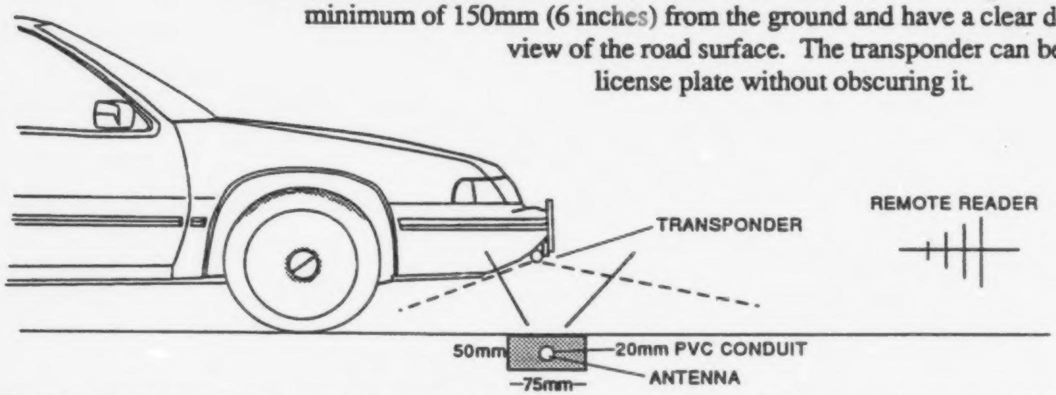


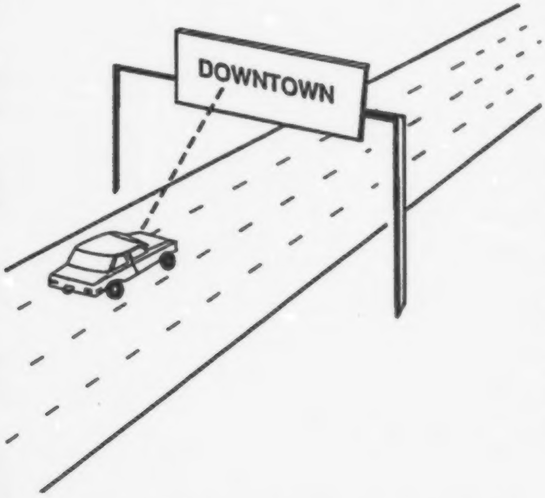
Diagram of a car-mounted transponder interacting with an in-pavement antenna. The transponder attaches to the license plate without obscuring it in any way. The car does not have to stop or even reduce speed in order for ROADCHECK to identify it.

Overhead antenna installation

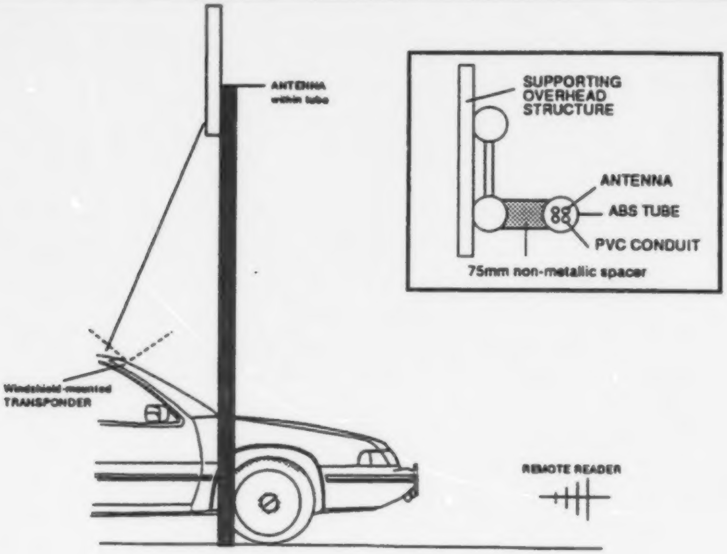
ROADCHECK can also be used in an overhead antenna configuration. Transponders are mounted on the inside of the windshield.

The ROADCHECK overhead antenna system consists of a bundle of 20mm PVC tubes within a larger ABS tube. Each PVC tube contains an antenna which spans the lane to be covered. Radiation patterns in this configuration provide the same controlled trigger fields and lane distinction as the in-pavement configuration.

The antenna assembly may be attached to any overhead structure as long as it is kept at least 75mm (3") from metallic surfaces.



An overhead ROADCHECK installation. Each lane's antenna is encased in a PVC conduit contained in an ABS tube. Windshield-mounted transponders are identified as the vehicle passes under the overhead structure.



Side view of vehicle with windshield-mounted transponder passing under an overhead antenna installation. Inset shows magnified cross section of antenna installation.

The main advantage of this approach is that transponders are better protected from vandalism and theft and can be read easily with a portable reader. Furthermore, application of temporary tags is greatly simplified.

It must be noted that in actual free flow traffic situations several technical shortcomings of overhead reading have been observed, regardless of the type of AVI technology used.

Despite antenna adjustments to compensate for vehicle height and windshield configuration, read reliability suffers due to factors such as variations in the "home" position of windshield wipers, application of energy absorbant windshields, variations in windshield angle and the shadowing effect of large vehicles on smaller ones. In addition, systems using high energy microwave beams increase potential driver radiation exposure.

Suitable for all types of vehicles: ROADCHECK's practical in-pavement and overhead configurations are suitable for all types of vehicles. In-pavement installation does not require adjustment of reader interrogator beams and potential clearance problems associated with overhead antennas are avoided. However, windshield-mounted transponders facilitate temporary applications and are less liable to theft or vandalism.

Flexible: Transponders may also be installed to look out as well as down. While this arrangement may limit transponder installation, it permits transponders to be read by a remote reader up to 30m (100 feet) from the vehicle. This can be exploited for system enforcement.

Easy to install: Installation of the transponder reader and antenna is simple. The reader electronics are housed in a weatherproof box mounted above ground level on a pole or other suitable roadside structure. A 75mm x 50mm (3" x 2") slot cut or cast in the roadway spanning the lane to be covered is all that is necessary for antenna installation. In the overhead system configuration, the antenna assembly may be attached to any overhead structure as long as it is separated from metallic surfaces by at least 75mm (3").

Multi-lane capability: Complete coverage of each lane, and by extension, the entire width of the roadway, is accomplished by one slot and an appropriate feed line. The antenna structure is bonded to the road so that it is flush with the surface. In the case of overhead installation, complete coverage is achieved by one ABS tube and an appropriate feed line. The ABS tube enclosed antenna affixes easily to any overhead structure.

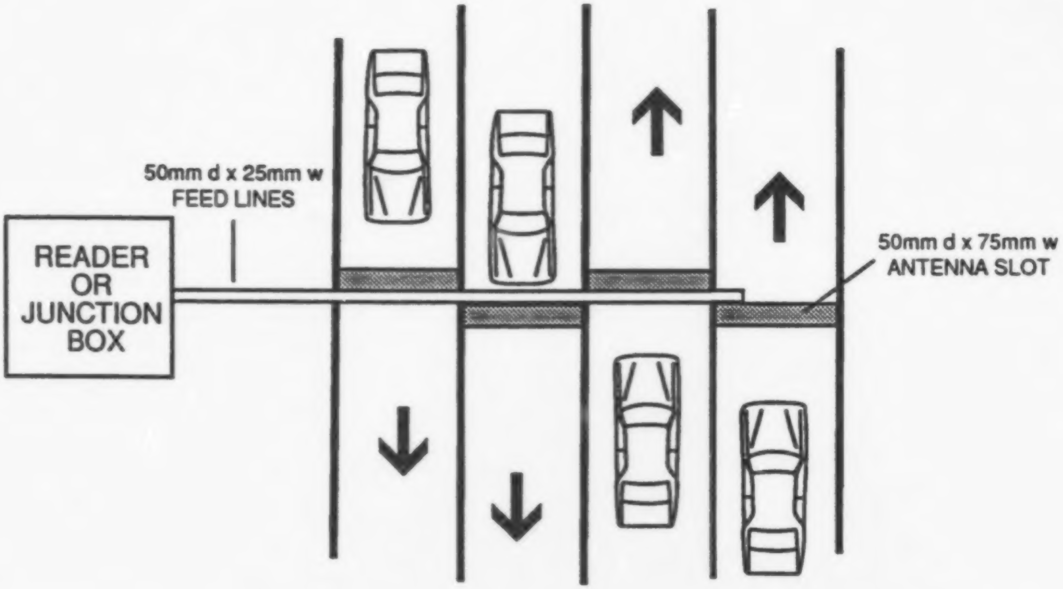
Easy to maintain: Periodic service requirements are met by simply pulling the flexible antenna through a conduit built into the antenna structure.

SYSTEM OPERATION

The reader system periodically transmits RF pulses using a 915 MHz carrier from the antenna. If a transponder is present, it detects these pulses and responds with its identification number and other data via a modulated 915 MHz signal.

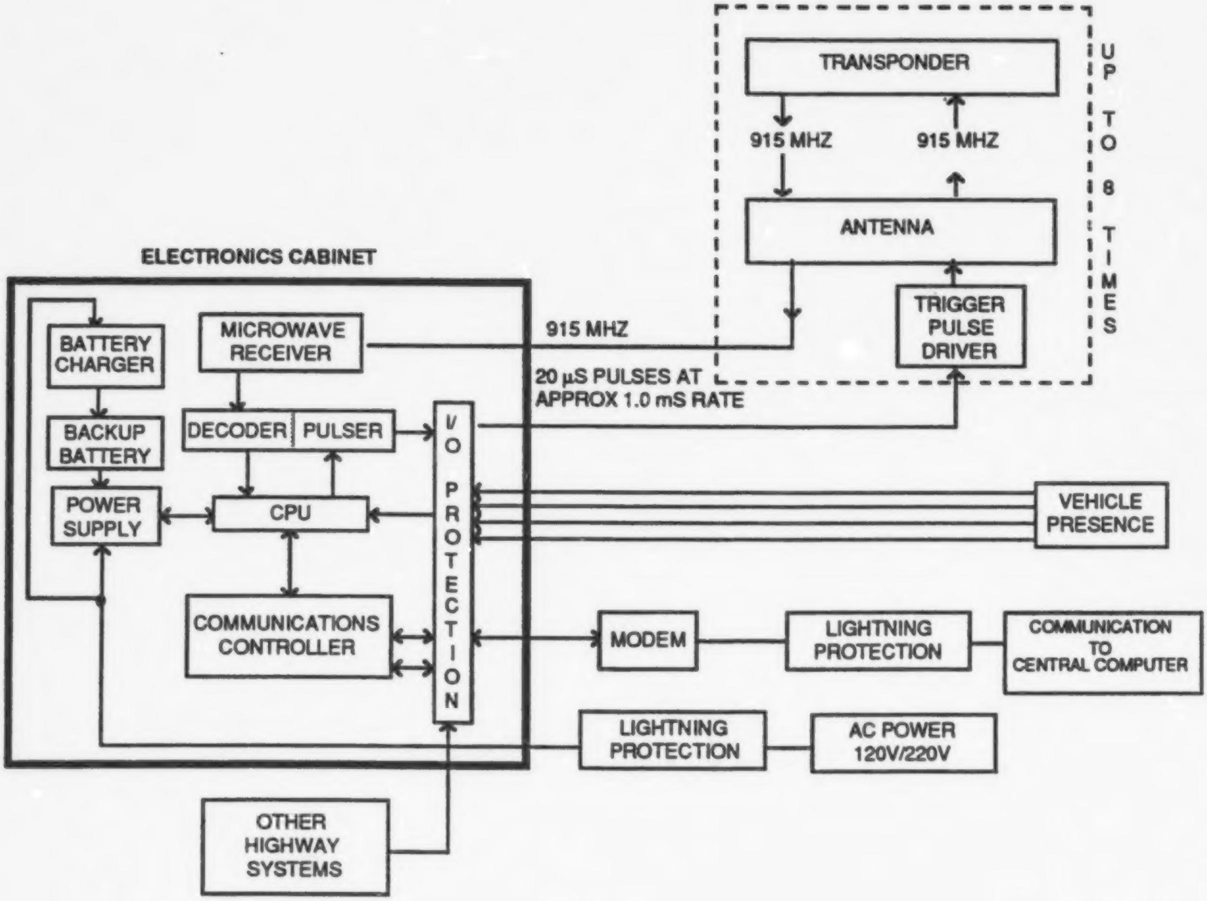
Since the transponder has its own lithium cell, a high-power interrogating beam is not required. This eliminates any potential biological hazard and drastically reduces the possibility of interference with other systems. In addition, ROADCHECK's relatively high energy data signal provides excellent noise and interference immunity.

ROADCHECK's high data rate (500 Kbits/second) permits the interrogation procedure to be performed on other lanes before it is necessary to repeat the task on the same lane. ROADCHECK can therefore handle up to an eight lane divided highway using only a single reader system with multiplexed antennas. Apart from the obvious economic benefits, this approach simplifies the communications and data handling systems required, improving overall system reliability and further reducing system costs.



Plan view of an in-pavement ROADCHECK highway installation. This diagram shows the set-up of a 4 lane highway with 2 lanes in each direction. As the car-mounted transponder passes over an antenna, it sends its ID and other relevant data to the reader box which then transmits the data to the central computer.

SYSTEM BLOCK DIAGRAM


TRANSPONDER
915 MHZ
915 MHZ
ANTENNA
TRIGGER PULSE DRIVER
UP TO 8 TIMES
ELECTRONICS CABINET
BATTERY CHARGER
MICROWAVE RECEIVER
915 MHZ
20 µS PULSES AT APPROX 1.0 mS RATE
BACKUP BATTERY
DECODER
PULSER
I/O PROTECTION
POWER SUPPLY
CPU
VEHICLE PRESENCE
COMMUNICATIONS CONTROLLER
MODEM
LIGHTNING PROTECTION
COMMUNICATION TO CENTRAL COMPUTER
LIGHTNING PROTECTION
AC POWER 120V/220V
OTHER HIGHWAY SYSTEMS

ADVANCED FEATURES

Multiple function tags

ROADCHECK transponders (or 'tags') are available with various levels of 2-way communications:

Type 1: Fixed code
Type 2: Fixed and reprogrammable fields
Type 3: 2-way communication with link to an on-board computer

These transponder types are fully compatible with each other and can be integrated with private transaction systems, on-board accounting systems and fleet management systems.

For example, Type 2 transponders can hold information on the vehicle's load status; dangerous loads can be monitored to ensure compliance with restricted zone regulations. Closed toll systems can program entry point data into the transponder. Debit/ Credit accounts can also be stored on Type 2 tags, allowing customers to verify charges.

Location updating and traffic information can be implemented using Type 3 transponders. These transponders communicate with computers installed on vehicles; traffic and safety advisories may be transmitted to motorists via an on-board computer (OBC). High security applications can employ frequently updated passwords and driver identification along with automatic access.

ROADCHECK's high data rate ensures that none of these optional features diminish system performance in any way.

System Enforcement

Since ROADCHECK can identify the lane in which tags are read, the realtime information needed to enforce road regulations can be easily acquired even under free-flow conditions.

In conjunction with a Vehicle Presence System, ROADCHECK can detect vehicles making unauthorized use of the roadway. The violation can be broadcast over police radio (or any other suitable radio channel) via a digital voice synthesizer. Violators can be identified in much the same way as speed violators are presently pinpointed by police using radar.

No special equipment is required: police officers need only tune their radios to the appropriate channel and observe the vehicles in the lane where the violation occured. Radio broadcasts can be localized and directional to avoid significantly adding to local radio channel traffic. The long range remote reader or the short range reader/ programmer may also be used as part of an integrated enforcement program.

TRANSPONDER SPECIFICATIONS

Number of data bits:	128
Data format:	Manchester coded keyed carrier
Number of preamble bits:	8
Error checking:	16 bit CRC
Data rate:	500 ±10% kbits per second
Data frequency:	915 MHz
Trigger frequency:	915 MHz
Mean radiated data power:	1μW
Operating temperature range:	-40° to 70° C
Dimensions:	46mm x 20mm x 230mm (1.75" x .75" x 9")
Weight:	approximately 200 g
Service life:	15 years (no external power required)
Mounting:	May be attached anywhere underneath the vehicle providing a clear line of sight with the road surface is maintained. Windshield mount is available for use with overhead antennas.

FIXED READER SPECIFICATIONS

Dimensions:	8 lane unit - 800mm high x 610mm wide x 300mm deep (30"high x 25"wide x 12" deep) in a self contained cabinet.
Mounting:	May be mounted independently on a pole or other suitable roadside structure.
Antenna:	Installs flush with roadbed in a slot 75mm wide x 50mm deep (3" wide x 2" deep) per lane of traffic. May be located up to 100m (325 ft) from electronics box if appropriate amplifiers and pre-amplifiers are used.
Overhead option:	Overhead mounted antennas may be used with windshield mounted transponders.
Power requirements:	120/240V, 50/60 Hz, 20W AC power; 12V DC battery optional. 4 hours per amp/hour backup provided.
Operating environment:	-40° to 70° C with internal heater. -15° to 70° C without internal heater. NEMA 4 cabinet. Protected against water and dust; suitable for high humidity environments.
Communications:	RS232C interface. Up to 9600 baud asynchronous. RS422A interface. 100,000 baud also available. Handshake protocols as desired.
Radiated power:	5µW/sq. cm average output at antenna surface (for use with Type I transponders).
Buffer:	Space for 10,000 AVI readings and associated data. 1 megabyte battery-backed static memory also available.
Lightning protection:	All inputs are protected by transorbs and/or optical coupling.
Reading speed:	Five reads at 160 Kmph with up to 8 vehicles present simultaneously.

PORTABLE EQUIPMENT SPECIFICATIONS

A portable Reader/Programmer is available for initial programming and field reading of transponders. The Reader/Programmer can also reprogram transponders.

Dimensions:	150mm wide x 200mm deep by 80mm high (6"wide x 8"deep x 3"high)
Weight:	3.5 kg
Operating range:	2 m (7 ft)
Power:	Internal rechargeable battery with 10 days operation under normal use.
Input:	Keyboard
Display:	Liquid Crystal Display (LCD)
Communications:	RS232C interface RS423/422A interface (optional)

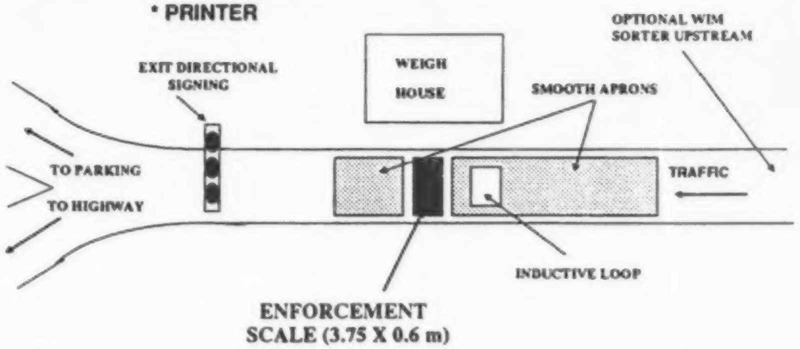
DATA DYNAMICS LOW SPEED WEIGH-IN-MOTION (WIM)

The Data Dynamics Low Speed WIM Enforcement System weighs vehicles travelling at speeds of 5-10 KPH (3-6 MPH), regardless of vehicle type and number of axles.

The Data Dynamics WIM Enforcement Model #100 weighs the vehicle as it rolls over the weigh scale and compares axle weights, axle group weights, and Gross Vehicle Weight (GVW) to allowable weight limits. Only those vehicles which violate the allowable weights or which fail to meet regulatory standards are required to stop at the Highway Inspection Station. Truck delays are reduced and continuous traffic flow is maintained due to: The speed of weighing vehicles; The elimination of traffic disruption; Simpler installation and maintenance; Integrated tracking of vehicles through the station.

MODEL #100 BASIC WIM ENFORCEMENT SYSTEM

WEIGH HOUSE CONTAINS:
- ENFORCEMENT SCALE COMPUTER
- DIRECTIONAL CONTROL SIGNS
- COLOR DISPLAY
- PRINTER


OPTIONAL WIM SORTER UPSTREAM
EXIT DIRECTIONAL SIGNING
WEIGH HOUSE
SMOOTH APRONS
TO PARKING
TO HIGHWAY
TRAFFIC
INDUCTIVE LOOP
ENFORCEMENT SCALE (3.75 X 0.6 m)

SYSTEM FEATURES

- Compact, Rugged, 100 % Environmentally Sealed Scale System
- Fully Frame Encased for Easy Scale Servicing
- Accuracy of $^{+}$/- 1.0% of GVW at 10 KPH
- Protected Against Surges, Lightning Strikes, and Unstable Line Voltage
- Off-scale Detection
- Axle Spacing and Vehicle Speed Determination

- * Keyboard and Selectable Screen Display Formats
- * Automatic Comparison of Individual Axle Weights, GroupAxle Weights, and Gross Vehicle Weight with Allowable Weights
- * World Wide Technical Support Staff Available For System Consultation, Installation, Commissioning, and Service

SYSTEM HIGHLIGHTS

Simple, Low Cost Operation

- * Light Weight, Rugged Scale System with Simple Installation Procedures
- * Easy Retrofit into Existing Systems
- * Simplified Maintenance with Standard PC-Based Hardware
- * User Friendly PC-DOS or MS-DOS Software and simplified user manual

Versatility

- * Flexible Hardware and Software Allows the System to be Adaptable to Different Weight Enforcement Programs, Complementary Systems and Accessories

TECHNICAL SPECIFICATIONS

Model #100 Low Speed WIM Enforcement System

WEIGHING SURFACE

DIMENSIONS:	**3.65m X 0.6m (144 in X 24 in) consistingof two platforms**
	each measuring 1.82m X 0.6m (72 in X 24 in)
CAPACITY:	**14,000 kg (30,800 lbs) per Wheel Load**
	28,000 kg (61,600 lbs) per Axle Load
ACCURACY:	**+/- 1.0% of GVW at 10 KPH (6 MPH)**
POWER:	**220v-50hz/110v-60hz AC supply**
CONTROL COMPUTER:	**IBM PC Compatible - MS-DOS Based**
	40 Megabyte Hard Disk
	512 Kilobyte Internal RAM Memory
	1.2 Megabyte Floppy Diskette Drive
	Enhanced Color Adapter (EGA) Monitor
OPERATING TEMP:	**-40°C to 80°C**
OPERATING HUMID:	**5% to 95% Relative Humidity**

CUSTOMIZED SYSTEMS

Data Dynamics specializes in expert design and custom systems. Data Dynamic engineers can tailor a system to meet your specific needs. Since 1978, The Data Dynamics group has developed and installed highway weigh-in-motion systems for transport agencies throughout the world.

OPTIONAL EQUIPMENT

Data Dynamics can complete your WIM site by furnishing several options to your WIM system:

- **Traffic and Weight Statistics Collection**
- **Integration with a Weigh in Motion Sorter System**
- **Telemetry Interface for Remote Data Retrieval**
- **Various On-Site Printers and Displays**
- **Weight Display Board**
- **Overhead and Wrong Lane Detectors, Directional Signals, and Variable Message Signs**
- **Closed Circuit TV and Photographic Camera Interface**
- **Automatic Vehicle Identification (AVI) or Electronic License Plate**
- **Radio Frequency (RF) Signal Control and Transmission of Data**

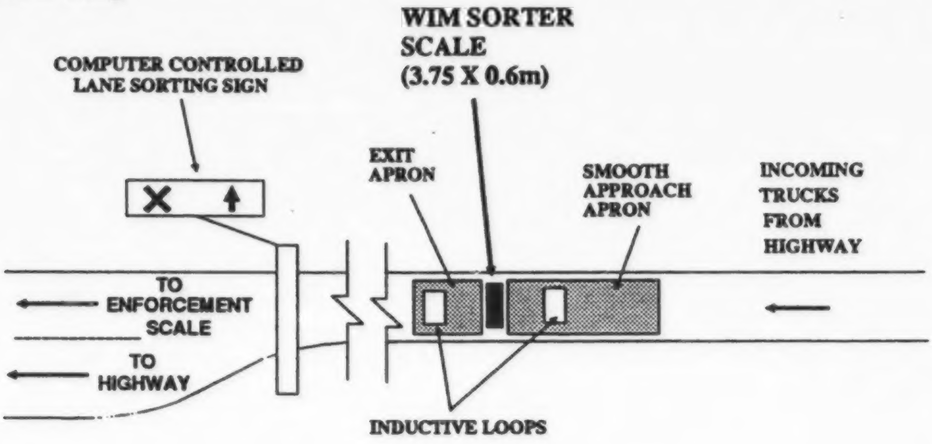
DATA DYNAMICS WEIGH-IN-MOTION (WIM) SORTER

The Data Dynamics WIM Sorter weighs vehicles at medium to high speeds (up to 120 KPH or 72 MPH). The WIM Sorter Model #200 automatically pre-screens or sorts overweight trucks from non-violating vehicles as they travel over the sorting system.

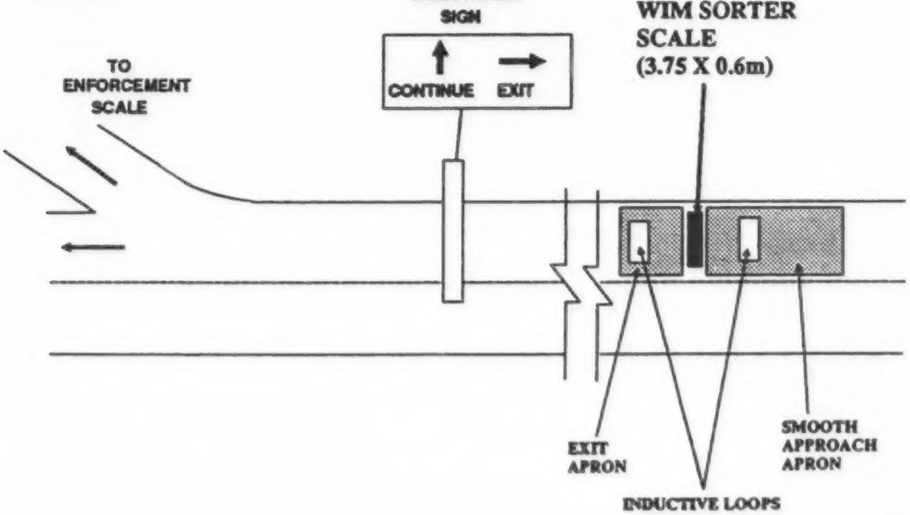
The Model #200 compares individual axle weights, axle group weights, and Gross Vehicle Weight (GVW) with allowable weight limits, and sorts those vehicles which are overweight or which fail to meet regulatory standards.

BASIC SORTER CONFIGURATIONS

Separate Lane Sorting


WIM SORTER SCALE (3.75 X 0.6m)
COMPUTER CONTROLLED LANE SORTING SIGN
X ↑
EXIT APRON
SMOOTH APPROACH APRON
INCOMING TRUCKS FROM HIGHWAY
TO ENFORCEMENT SCALE
TO HIGHWAY
INDUCTIVE LOOPS

Main Lane Sorting


DIRECTIONAL SIGN
↑ CONTINUE
→ EXIT
WIM SORTER SCALE (3.75 X 0.6m)
TO ENFORCEMENT SCALE
EXIT APRON
SMOOTH APPROACH APRON
INDUCTIVE LOOPS

SYSTEM FEATURES

- Compact, Rugged, 100% Environmentally Sealed Scale System
- Fully Frame Encased for Easy Scale Servicing
- Systems are Easily Installed in New or Existing Pavements
- Accuracy of 3.0% of GVW at 40 KPH (25 MPH)
- Protected Against Surges, Lightning Strikes, and Unstable Line Voltage
- Off-scale Detection
- Axle Spacing and Vehicle Speed Determination
- Keyboard and Selectable Screen Display Formats
- Automatic Comparison of Individual Axle Weights, Group Axle Weights, and Gross Vehicle Weight with Allowable Weights
- Sorter Can be Installed in a Main or Exit Lane
- World Wide Technical Support Staff Available For System Consultation, Installation, Commissioning, and Service

SYSTEM HIGHLIGHTS

Simple, Low Cost Operation

- Light Weight, Rugged Scale System with Simple Installation Procedures
- Easy Retrofit into Existing Systems
- Simplified Maintenance with Standard PC-Based Hardware
- User Friendly PC-DOS or MS-DOS Software and Simplified User Manual

Versatility

- Flexible Hardware and Software Allows the System to be Adapted to Different Weight Enforcement Programs, Complementary Systems and Accessories

TECHNICAL SPECIFICATIONS

MODEL #200 Weigh-In-Motion (WIM) SORTER

WEIGHING SURFACE	
DIMENSIONS:	3.65m X 0.6m (144in X 24in) consisting of two platforms each measuring 1.82m X 0.6m (72 in X 24 in)
RATED CAPACITY:	14,000 kg (30,800 lbs) per Wheel Load 28,000 kg (61,600 lbs) per Axle Load
ACCURACY:	$^{+}$/- 3.0% of GVW at 40 KPH (25 MPH)
POWER:	220v-50hz/110v-60hz AC supply
CONTROL COMPUTER:	IBM PC Compatible - MS-DOS Based 40 Megabyte Hard Disk 512 Kilobyte Internal RAM Memory 1.2 Megabyte Floppy Diskette Drive Enhanced Color Adaptor (EGA) Monitor
OPERATING TEMP:	-40°C to 80°C
OPERATING HUMID:	5% to 95% Relative Humidity

CUSTOMIZED SYSTEMS

Data Dynamics specializes in expert design and custom systems. Data Dynamic engineers can tailor a system to meet your specific needs. Since 1978, The Data Dynamics group has developed and installed highway weigh-in-motion systems for transport agencies throughout the world.

OPTIONAL EQUIPMENT

Data Dynamics can complete your WIM site by furnishing several options to your WIM system:

- Traffic and Weight Statistics Collection Software
- Integration with Weight Enforcement Systems
- Telemetry Interface for Remote Data Retrieval
- Overhead and Wrong Lane Detectors, Directional Signals, and Variable Message Signs
- Closed Circuit TV or Photographic Camera Interface
- Automatic Vehicle Identification (AVI) orElectronic License Plate
- Radio Frequency (RF) Signal Control and Transmission of Data
- Various Printers and Output Devices

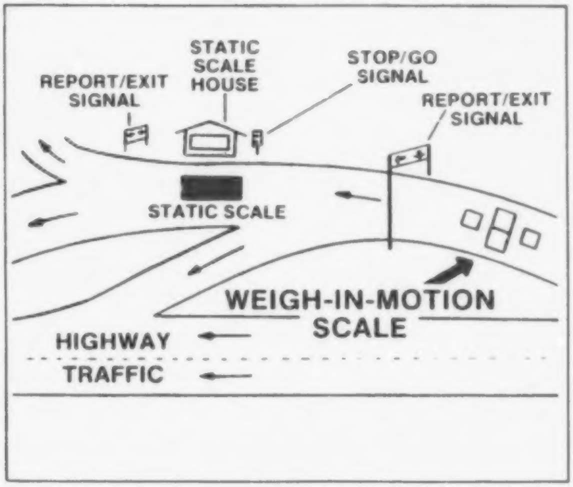
INTERNATIONAL ROAD DYNAMICS, INC.

HIGH SPEED WEIGH-IN-MOTION SCALE SYSTEM

PRODUCT INFORMATION

Features of the IRD HIGH SPEED WIM:

- Dynamic Weighing — Weighs Vehicles at Normal Highway Speeds
- Time, Date, Speed, Axle Weights and Gross Vehicle Weight
- Wide Range of Accessories Including Automatic Vehicle Identification, Over Height Detectors, Wrong Lane Detection, Directional Signals and Information Signs
- Weight Enforcement, Sorting and Data Collection
- Computer Controls Directional Signals and Signs


STATIC SCALE HOUSE
REPORT/EXIT SIGNAL
STOP/GO SIGNAL
REPORT/EXIT SIGNAL
STATIC SCALE
WEIGH-IN-MOTION SCALE
HIGHWAY
TRAFFIC

APPLICATIONS

1) Sorting

- Automatic Sorting of Violating Trucks from Non-Violating Trucks Prior to an Inspection Station
- Directional Signals Automatically Direct Trucks Through the Station to Report to the Weigh House or to the Bypass Lane and back to the Highway

2) Data Collection

- Highway Traffic Data Collection for:
  - Pavement Design and Performance
  - Bridge Design and Evaluation
  - Transport Planning
  - Establishing Current Traffic Demand and Forecasting Future Trends
  - Establishing Budgets for Highway Maintenance, Reconstruction and New Construction

SAMPLE OUTPUTS

```
Tues., Feb. 17     05:49:02     1987     Lane 1
Weight: 52.7 tonnes — overweight
Type: UD-6
18-K ESAL: 10.130
Speed: 53 km/hr

   Axle       Spacing (cm)       Weight (tonnes)
    1             489                 5.2
    2             159                 9.8
    3             579                 8.9
    4             316                 11.7*
    5             180                 9.1
    6              —                  8.2
* overweight axle loading
```

```
LANE 1      TYPE 16              GR WT 59.4 tonnes
Speed: 102 km/hr       Fri., Jan. 30   09:24:26   1987
|<------------------- 31.9 m ------------------->|
  0      0      0      *      *      0      0      0
 5.1    7.8    8.8    9.7    8.2    7.7    8.0    4.1
- - - - - - - - - - - - - - - - - - - - - - - - - - -
LANE 1      TYPE 8               GR WT 32.3 tonnes
Speed: 93 km/hr        Fri., Jan. 30   09:24:28   1987
|<---------- 16.8 m ---------->|
  0      0      0      0      0
 6.8    6.9    7.1    6.6    4.9
* overweight axle loading
```

TECHNICAL SPECIFICATIONS

Operating Environment

- Temperature -50°C to +50°C (-58°F to +122°F)
  - No Temperature Correction Required
- Capacity
  - Maximum Single Axle Load of 20 Tonnes (22 tons)
  - Tested at 10,000,000 Applications

Environmental Protection

- Sealed From Water, Dirt, Sand, Salt and Other Debris
- Surface of Scale Installed Flush with the Surface of the Roadway and is not Affected by Roadway Cleaning, Ice or Snow Removal Operations
- Electronics Protected From Power Surge and Lightning

Output

- On-Site via CRT, Printer or Both
- Remote via Modem and Telephone Lines

Physical

- Platform Size 61 cm x 162 cm x 20 cm (24" x 64" x 8")

APPENDIX H

TRAVTEK

'SMART CAR' PROJECT IN ORLANDO

APPENDIX I

TRAVTEK

[CONTRACT SIGNED FOR $8 MILLION 'SMART CAR' PROJECT IN ORLANDO]

An agreement to implement the most comprehensive Intelligent Vehicle/Highway System (IVHS) project in this country was signed today by U.S. Secretary of Transportation Samuel K. Skinner, Florida Assistant Secretary of Transportation Frank Carlile, Orlando Mayor Bill Frederick, and top officials of General Motors Corporation and the American Automobile Association.

Funding for the program is $8 million. System development will begin immediately, while operations are planned for early 1992.

Called **TravTek** (short for travel technology), the IVHS project will provide navigation assistance, real-time traffic information, route selection and other information to tourists and business travelers in the Orlando area.

This information will be supplied to drivers of 100 specially equipped Oldsmobile Trofeo models. There will be 75 rental cars for use by AAA members and 25 vehicles assigned to high-mileage local drivers.

Primary objectives are to determine technical feasibility of such a system, user acceptance and reduction in travel times. Other potential benefits to be studied include increased safety, fuel savings and improvements in air quality.

Putting TravTek in national perspective, Secretary Skinner said: "The partnership sponsoring TravTek is just the kind of public/private agreement that will be necessary to undertake the research and technological advances needed to improve America's transportation system for the 21st century."

"President Bush's new National Transportation Policy aggressively encourages such partnerships," he said. "We expect in-vehicle information systems to provide for enhanced safety, more effective use of the transportation network and increased commercial fleet productivity."

General Motors is the overall program manager and systems engineer for the experiment. In addition, GM has responsibility for producing the vehicles with necessary on-board navigation and communication technology. The TravTek vehicles will advise drivers via electronic maps, symbolic displays and synthesized voice. They also will indicate their position and status to the Traffic Management Center.

"While we're testing the technical systems, we are particularly interested in the human-factors side of the project," said Alan Smith, GM executive vice president. "We want to see how customers react to and use the equipment. General Motors wants to ensure that automotive travel is both enjoyable and efficient."

AAA will have responsibility for the TravTek Information and Services Center, including the navigation data base. AAA will provide electronic maps, as well as events calendars and driver information, and supply on-line information services to the TravTek vehicles. AAA will select drivers for the program through its network of 151 clubs in the United States and Canada.

"AAA is proud to provide the data base of maps, events, hotel, restaurant and other information for TravTek," said AAA President James B. Creal. "Motorists want more immediate information. TravTek will showcase our ability to provide that information and make driving a more pleasurable experience."

The **Federal Highway Administration** and the **City of Orlando** will develop and operate the Traffic Management Center. The center collects traffic data from a number of sources such as police reports, freeway surveillance and the traffic signal system. It will poll the TravTek fleet for position and speed, calculate travel times using the AAA data base, and transmit real-time information to the vehicles. Drivers can access traffic conditions, travel times, map updates and events.

The **Florida Department of Transportation** will design, install and operate the freeway surveillance and control system along Interstate 4 in the metropolitan Orlando area. This will consist of in-road sensor devices, cameras and a monitoring station to immediately determine the location and cause of traffic congestion.

The system will enable rapid dispatching of needed rescue and removal equipment to problem areas.

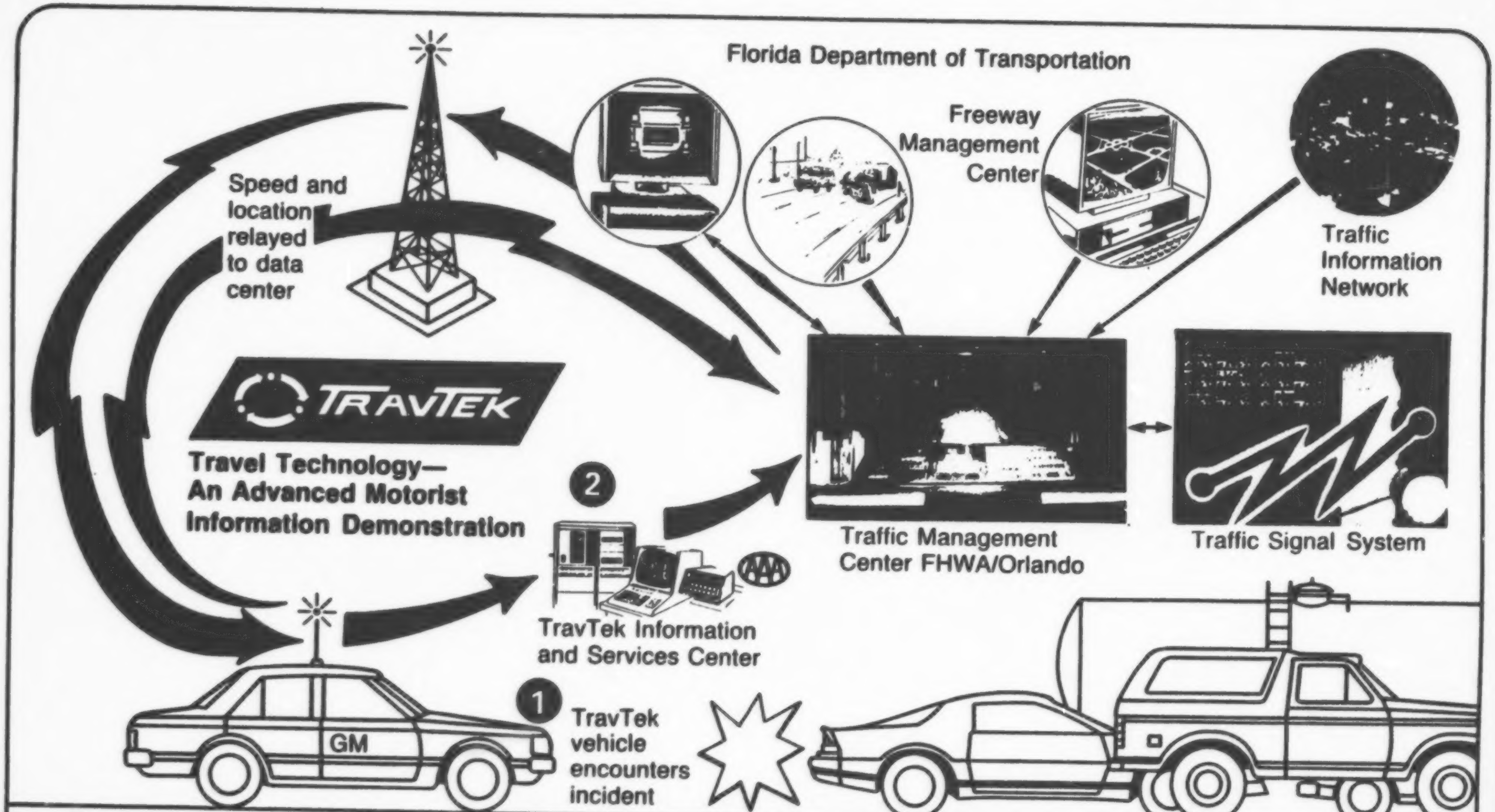
"The growth of tourism and our rapid development as a major metropolitan area makes us a natural test site for TravTek's cutting-edge technology," said Bill Grederick, mayor of Orlando.

Added Asst. Secretary Carlile: "The Florida Department of Transportation has made quite a commitment to this project. I envision real benefits for both Floridians and the tourists of this state."

The TravTek signing ceremony occurred at an IVHS national leadership conference sponsored by the Highway Users Federation, the U.S. Department of Transportation and General Motors.

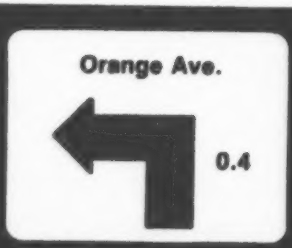
TravTek Timetable

Prototype Test	Late summer 1990	
Production	Hardware	February 1991
	100 Vehicles	June 1991
Operation	Commences in	January 1992
Duration	Experiment continues until January 1993	
Vehicle Disposition	Vehicles will be repurchased from the car rental agency, TravTek equipment removed and the vehicles resold as used cars early 1993.	


Florida Department of Transportation
Speed and location relayed to data center
Freeway Management Center
Traffic Information Network
TRAVTEK
Travel Technology—An Advanced Motorist Information Demonstration
2
Traffic Management Center FHWA/Orlando
Traffic Signal System
TravTek Information and Services Center
1
TravTek vehicle encounters incident
GM

The in-vehicle TravTek device will consist of a video screen, a microcomputer, and a radio for data communications. The video monitor may display any of the following:

ORLA
CANTON ST
ROBINSON AVE
SOUTH ST
EXPWY
AVE


Orange Ave.
0.4

Orlando Hotel
◊◊◊ $$
427 Main Street
Parking, pool, lounge
No pets, kitchenettes

TRAVTEK FACT SHEET

TravTek is a three-year joint venture between government and private enterprise to test an intelligent vehicle/highway system in Orlando, Fla., that will bring American automobile travel into the next century.

Special equipment in 100 experimental cars will give drivers access to instant video maps, directions within the area, current traffic conditions, route suggestions and hotel and restaurant information.

Of the 100 cars in the experiment, 75 will be used by tourists and 25 will assigned to local, high-mileage drivers. The experiment will help partners in the venture understand the technical feasibility of TravTek, its acceptance by motorists and its impact on travel.

Quick Facts:

Project Cost: $8 million - shared among GM, FHWA, FDOT, AAA

Time Frame:
- Computers and system software now being developed
- Oldsmobile Trofeos and TravTek terminals ready by late 1991
- Traffic Management Center ready by late 1991
- TravTek experiment to begin early 1992

Components:

- 100 "Smart" Vehicles
- Traffic Management Center
- TravTek Information and Services Center

Potential Benefits:

Reduced traffic congestion, enhanced travel experience, fuel savings, improved air quality and increased safety.

Partners and their Contributions:

The American Automobile Association will provide the computerized data base of maps and other information. It will develop agreements with rental car agencies, recruit customers and inspect and maintain TravTek units.

General Motors Corporation will provide 100 Oldsmobile Trofeos and TravTek units. GM will act as project manager and oversee system engineering.

The Federal Highway Administration (FHWA) will help plan and develop the Traffic Management Center to monitor traffic conditions and process information for TravTek.

The City of Orlando will set up and staff the Traffic Management Center.

The Florida Department of Transportation (FDOT) will provide computerized, video traffic surveillance Interstate 4, which is part of the test area.

May 1990

A Public-Private Partnership

A TravTek (travel technology) project is being developed for the entire Orlando area. This project is a cooperative partnership that includes the following organizations:

- *General Motors (GM)*
- *Federal Highway Administration*
- *American Automobile Association (AAA)*
- *Florida Department of Transportation*
- *The City of Orlando*

The TravTek system uses prototype, in-vehicle information equipment that will provide motorists with up-to-date traffic information, and directions to the destinations. In addition, the TravTek system offers useful information about Orlando-area attractions, accommodations, and services.

The Project

TravTek equipment will be installed in about 75 general-use GM rental cars and about 25 vehicles used by high mileage local drivers, such as salespersons. While traveling the Orlando area, these drivers will receive continuous reports about congested routes to avoid. As new information becomes available on traffic incidents (accidents, disabled vehicles, construction and maintenance activities, etc.), drivers will be offered alternate routes that reflect the shortest travel times on the highway network.

The cost of the TravTek system, including operations for a one-year period beginning in 1992 and subsequent evaluations, is estimated to be $8 million. The private and public sector partners will share the cost of the project.

In-vehicle motorist information systems will provide for enhanced safety, more effective use of the transportation network and increased commercial fleet productivity. This project will contribute significantly as this country advances the design of such systems to serve motorists.

How TravTek Works

The in-vehicle TravTek device will consist of a video screen, a microcomputer, and a radio for data communications. The video monitor may display any of the following:

- Maps of the Orlando area graphically representing traffic congestion locations, incidents, and services information.
- Text information about traffic incidents or available services.
- Route guidance instructions using simple graphical cues, such as directional arrows.

When drivers select destinations, the TravTek processor uses travel times to determine the best routes. The TravTek system uses both graphic displays and a synthesized voice to give information to drivers.

In addition to route instructions, drivers can view services available in the Orlando area. On the video monitor, service stations, hotels, motels, restaurants, or tourist attractions may be indicated on a map display or viewed as textual information. Drivers also may place a call to a listed establishment via a dedicated cellular telephone.

The Traffic Management Center

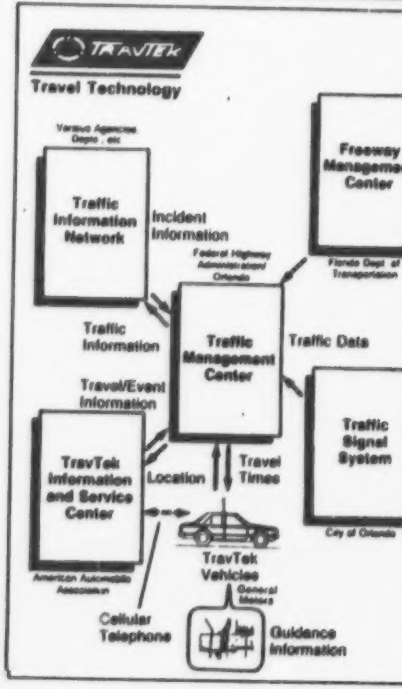
A traffic management center will combine and sort ("fuse") the traffic-related information received from a variety of sources throughout the Orlando metropolitan area that will make up the Traffic Information Network (TIN). The TIN will include, among others, the following sources:

- The City of Orlando's centralized traffic signal system.
- The Florida Department of Transportation's freeway management systems.
- The American Automobile Association's TravTek Information and Service Center.
- The police agencies in the area.
- The various departments responsible for maintenance and construction activities.
- The TravTek vehicles, themselves.

From this fused data, information on incidents, including travel times on affected routes, is estimated and transmitted to the TravTek vehicles. The in-vehicle TravTek processor then determines if the driver's selected route is affected, calculates a new routing, and informs the driver that a revised routing is available.

The diagram at the right shows the various components of TravTek and the responsibilities of the participants. The TravTek project is a reflection of the kinds of partnerships encouraged by the National Transportation Policy.

This project also will supply beneficial data, which can be used to advance the design of driver information systems. Evaluations of systems, such as TravTek, promote research and technological innovations that must take place to increase the efficiency of our highway network.


Travel Technology
Various Agencies Depts., etc.
Traffic Information Network
Incident Information
Federal Highway Administration Orlando
Freeway Manageme Center
Florida Dept. of Transportation
Traffic Information
Traffic Management Center
Traffic Data
Travel/Event Information
Traffic Signal System
City of Orlando
TravTek Information and Service Center
American Automobile Association
Location
Travel Times
TravTek Vehicles
General Motors
Cellular Telephone
Guidance Information